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COMMONWEALTH OF AUSTRALIA

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OF

THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

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*314 Albert Street,
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A Review of the Work of C.S.I.R.

By G. Lightfoot, M.A.

As at present constituted by the *Science and Industry Research Act* 1926-39, the Council consists of three members nominated by the Commonwealth Government (one of whom is Chairman), the Chairmen of the six State Committees, and other members co-opted by reason of their scientific knowledge. The three Commonwealth Government appointees form an Executive Committee which exercises all the powers and functions of the full Council in the intervals between its meetings.

The activities of C.S.I.R. have necessitated a widespread and adaptable organization. Undesirable centralization has been avoided mainly in two ways. In the first place the policy has been followed of establishing laboratories in different places in the Commonwealth wherever the necessary facilities, contacts and other suitable conditions could best be found. Secondly, a State Committee, widely representative of scientific and industrial interests, has been established in each of the six States. These Committees advise the Council on general matters and on particular questions of investigation and research.

For about twelve years after its establishment the work of C.S.I.R. was devoted mainly to the solution of problems affecting the agricultural and pastoral industries. Unlike manufacturing concerns, which can often employ their own scientific staffs, the farmer and the pastoralist are dependent on outside help for the solution of their problems which require research. It was a recognition of the greater need of the primary producer which directed the Council's early policy. However, in 1937 the Commonwealth Government decided to extend the activities of C.S.I.R. so as to provide assistance to secondary industries and the Council proceeded to establish several laboratories for work in that field; it was thus in the fortunate position of being able to render to these industries assistance of vital importance almost immediately after the outbreak of war. In fact, the remarkable technological advances and developments in secondary industrial production during the war would to a large extent have been impossible had it not been for the assistance rendered by scientific research, and this may well serve as a forceful illustration of what may be accomplished in times of peace.

For the purpose of carrying out its research work the Council has established a number of Divisions and Sections. The Divisions, of which there are now twelve, comprise the major establishments for which special laboratory buildings have been erected and equipped;

the Sections generally include establishments which have not reached a stage of development, so far as the scope and magnitude of their operations are concerned, to justify their designation as Divisions. As the Council's investigations extend on a Commonwealth-wide basis and as many of the investigations which are being conducted—particularly those concerned with problems affecting the agricultural and pastoral industries—necessitate experimental work in the field, a number of field stations have been established in various parts of Australia.

The Divisions which have been established are as follow:—

1. Plant Industry, with main laboratories at Canberra and field stations.
2. Economic Entomology, also with main laboratories at Canberra and field stations.
3. Animal Health and Production, with main laboratories in Melbourne and Sydney and field stations.
4. Biochemistry and General Nutrition, with main laboratories at Adelaide and field stations.
5. Soils, also with main laboratories at Adelaide and extensive operations in the field.
6. Forest Products, with main laboratories in Melbourne and field experiments.
7. Food Preservation and Transport, with main laboratories at Homebush, N.S. Wales, and a subsidiary laboratory in Brisbane.
8. Fisheries, with main laboratories at Cronulla, N.S. Wales, and experimental work in coastal waters of Australia.
9. National Standards Laboratory at Sydney.
10. Radiophysics Laboratory, with main laboratory at Sydney and subsidiary laboratory at Melbourne, and operational research groups.
11. Aeronautics, with laboratories in Melbourne.
12. Industrial Chemistry, with laboratories in Melbourne.

The following are the Sections:—

1. Research Station, Murray Irrigation Area, Merbein, Vic.
2. Irrigation Research Station, Griffith, N.S. Wales.
3. Lubricants and Bearings, Melbourne.
4. Dairy Products, Melbourne.
5. Mineragraphic Investigations, Melbourne.
6. Ore-dressing Investigations, Melbourne, Adelaide, and Kalgoorlie.
7. Building Materials Research.
8. Section of Mathematical Statistics.
9. Scientific Liaison and Information Bureau.

The activities of C.S.I.R. are now so comprehensive and so widely distributed that it is not an easy matter to present in a concise form an adequate picture of them. In the following paragraphs an attempt is made to give a brief account of the Council's work, with some examples of the results which have been achieved, and to indicate the directions in which assistance must be given by scientific research for the further utilization of our resources and the development of our industries.

1. Plant Industry.

Before the war this Division was engaged in investigations for the benefit of the agricultural and pastoral industries. It carried out research into the improvement of pastures, both in low and high rainfall areas; the breeding of plants to give higher yields and to be resistant to drought and disease; the eradication of weed pests; the introduction of pasture and other plants from other countries especially suited to Australian conditions; and the control of diseases of plants such as tomatoes, apples, pineapples, potatoes, flax, peas, and hops.

An outstanding achievement was the discovery of a simple, practical and economic method of controlling blue-mould in tobacco seedlings by using the vapours of certain hydrocarbons, notably benzol and toluol; this disease was previously the most serious factor in preventing the development of a successful tobacco industry in Australia. The Division has solved the problem of bitter-pit in apples, a storage disease which cost the export trade £100,000 a year. It has developed varieties of potatoes free from virus diseases, which frequently cause losses of up to 25 per cent. or more in the potato crops. It has discovered a simple method for the control of water-blister in pineapples. It has introduced and acclimatized thousands of pasture and other plants, some of which show very great promise, and it has achieved marked success in the control of certain weed pests.

Following the outbreak of war, new and urgent problems arose and much of the above work had to be abandoned or left partly in abeyance. For example, Australia's dependence on other countries for vegetable seeds created a most serious situation which was tackled by the Division, with the result that supplies of seed are now maintained successfully despite many difficulties and setbacks. Many problems concerned with the cultivation, manuring, &c., of vegetables had to be solved. Again, the shortage of drugs from medicinal plants gave rise to serious problems; success attended the work of the Division and materials have been found and processes evolved for producing no less than eight of the drugs. For the indispensable drugs atropine and hyoscine an excellent source of supply was found in a native shrub, and it is not unlikely that the world's supply of hyoscine may come from this source after the war.

When peace comes the normal work of the Division must be resumed and extended. The control of weeds will be an even greater problem than previously because of their spread under conditions of manpower shortage. If it is the policy of the Government to maintain a flourishing tobacco-growing industry in Australia much further work in the way of research remains to be done. There is an important field of work in connexion with the production of flax and other fibre plants. Virus

diseases of many crops are increasing in range, complexity, and importance, whilst soil-borne diseases of crops, such as wheat, maize, and peas form another group of problems for research. Plant breeding to obtain improved varieties of crop plants will be as essential after the war as before.

In view of the profound importance of wool and meat in our national economy and of the deterioration which is taking place in pastures over many wide areas, investigations to improve our pastures must be developed. The developments which may be anticipated would be of the utmost significance in the post-war period and would form a very substantial contribution towards increasing the population in the most vulnerable parts of the Commonwealth.

2. Entomology.

Insect pests are responsible for enormous losses to primary producers in Australia. The Division of Economic Entomology has been concerned mainly with problems which require long-range research. It already has a substantial record of achievement to its credit.

The sheep blowfly may cause a loss of £4,000,000 in a bad year and its control has proved to be a complex and difficult problem. Investigations, some of which were partially successful, were conducted to find a method of control by trapping, the introduction of parasites from other countries, the poisoning of carcasses on which insects breed, and sprays and repellents. Several new blowfly dressings have been evolved, and a surgical procedure—a modified Mules operation—has been developed and has given virtual control of blowfly strike on the crutch of sheep.

Large numbers of cattle have died in Australia through tick infestation and spectacular control of ticks in small-scale tests has been obtained by the use of sprays of the synthetic preparation known as D.D.T. The buffalo-fly pest threatened to be a most serious menace to the dairy herds of the coastal areas of Queensland. The Division has shown that by the use of special traps the number of flies attacking a herd can be reduced to a very low level and that cattle can be protected against attack by the use of sprays.

White ants cause great destruction. The Council's entomologists have now obtained a thorough knowledge of the different species of these insects and their habits, and this knowledge has been extremely useful. For example, when certain buildings were being erected in the A.C.T. the heavy termite infestation of the land caused some concern. This was dispelled when it was pointed out that the species were purely grass-eating and did not attack timber. Effective methods of preserving different timbers from termite attack have been evolved and a cheap and effective way of destroying termite colonies has been found; the latter was of particular importance owing to the fact that aerodromes in parts of Australia were often made dangerous by termites building mounds on them. These mounds may be built up overnight to a height of from six to eight inches.

Wheat pests can readily be controlled in ordinary silos, but under wartime conditions it was found necessary to store very large quantities of wheat either as bag stacks or in enormous piles of loose wheat. Under

these conditions the ordinary methods of control could not be used. Investigations were conducted and methods evolved whereby control of the pests could be obtained. During the war enormous quantities of wool have been held in store in Australia and there was a probability of great loss through insect infestation. Investigations were conducted and showed that the pests were confined to the outer two inches of the bales; effective control has been obtained by spraying the bales with special oils.

The conquest of prickly pear is a classic example of biological control and this method has played an important part in the Division's investigations. Insects introduced to combat the serious weeds lantana and St. John's wort are now well established in most of the infested areas and are already destroying the weeds. The green-house white fly has been brought under effective control by the introduction of a parasite from the Oriental region. Parasites of the potato moth and the cabbage butterfly, both very serious pests, have been established in the field, and parasites of several other pests are being handled under experimental conditions.

The work of the Division has been confined to outstanding problems of economic importance, but there are several major problems and a host of less urgent ones not yet touched. There is a large field of work on vegetable pests too numerous to mention. Pastures in certain parts of Australia are being ravaged by insect pests. Orchardists suffer severe losses from a number of different species of insects. There are many boring beetles and moths which damage both growing trees and timber. Virus diseases cause very serious damage to many crops and are usually transmitted by insects. Each pest problem has special features of its own and the many new insecticides and methods of application which have appeared during recent years demand much laboratory and field work.

It is obvious that there is a vast field of work awaiting attention. The control of one insect pest might well repay many times the total expenditure of the Division. The fight against insect enemies must be maintained and the only effective and economical method of conducting the campaign is by careful scientific investigation.

3. Animal Health.

One of the early problems tackled was pleuro-pneumonia in cattle, a most serious scourge in northern Australia. A vaccine has been developed which gives a high degree of immunity, and a very successful diagnostic test has been evolved whereby the disease is diagnosed in carriers, i.e., animals which show no symptoms of the disease but which harbour it and can transmit it to others. The Council's work on this problem has received world-wide recognition.

Mastitis is the cause of great loss to Australia's dairy industry. Bacteriological studies have disclosed a mass of important information and valuable results of world-wide interest bearing on methods of control have been obtained. Recommendations have been made for limiting the spread of the disease and alleviating losses.

Severe losses of beef cattle in the north are caused by tick-borne diseases, generally known as tick-fever or red-water. The organisms responsible are somewhat similar to those causing malaria in man. Officers of the Division have evolved an effective and safe method of conferring immunity by inoculation.

Foot-rot in sheep is a serious menace and occurs in some of our best sheep-raising country. The Council's investigators have shown that it can be eradicated completely from a flock by the simple method of systematic spelling of paddocks and treatment of the feet before returning the flock to clean paddocks. Successful and valuable results have been obtained from investigations into the control of internal parasites of sheep. Botulism in sheep in Western Australia, a disease associated with deficiency in diet, has been brought under control by the use of a vaccine. The cause of another disease, known as enzootic ataxia in lambs or Gingin disease—from the district in which it occurs in W.A.—has been discovered and remedial measures evolved. Effective control has been devised against the nodule worm, which was responsible for very heavy losses in sheep in summer rainfall districts. A method for controlling a new species of external parasite of sheep has been developed. Black disease of sheep was estimated to cause an annual loss of £1,000,000; the nature and cause of this disease have been determined and the disease has been brought under complete control. Another example is the control of entero-toxaemia in sheep, which became possible after the cause had been determined by intensive investigation.

The Division of Animal Health and Production had not reached maturity in its development before war broke out in 1939. There is need for vast improvement in our standards of animal production. In the sheep pastoral industry the control of bacterial and parasitic diseases has called for intensive research and very valuable progress has been made. Less attention has been given to production problems, though these are of extreme importance. If wool is to retain its position in the world's markets its price must be kept sufficiently low to bring it into favourable competition with artificial fibres; there are many problems to solve, not only in reducing actual expenditure on drought feeding, but also in preventing losses to stock by death from starvation. Further control of diseases would do much to prevent losses and to assist in lowering production costs. Each branch of the animal industry has its special production and disease control problems. In all branches breeding methods need overhaul. The production and conservation of fodder must be systematically planned and scientific feeding must replace present unscientific methods.

4. Animal Nutrition.

Soon after its establishment the Council received from many quarters evidence of the need for investigations into such questions as the composition of pastures from the points of view of their protein, mineral, and vitamin contents; the regeneration of depleted pastures; and the relations between growth of stock, nature of pasture, and geological type of country. The object was to obtain information whereby sheep in various localities and climates of Australia could be fed so as to yield the best economic results.

The investigations of the Division of Animal Health and Nutrition have already cleared up many problems connected with nutrition and wool production. For example, the nature of the so-called coast-disease has been ascertained and remedial measures applied with great success; this disease occurs in an area of 2,000 square miles of high rainfall country in South Australia alone and extends to Victoria, Western Australia, and King Island. The disease was found to be due to a dual deficiency of cobalt and copper and this has been remedied with most successful results.

Another example of deficiency occurred in parts of South Australia, where the symptom was a marked change in the character of the wool. The ordinary crimped staple ran out to a straight, lustrous growth; it was shown that the production of crimped wool invariably followed dosing the deficient animals with copper. As a result the value of the clips from copper-treated animals was increased by as much as 3s. per head. These discoveries have opened a new chapter in the development of immense areas in southern Australia: splendid healthy flocks are now depastured on these areas.

Investigations into the food requirements of sheep have established a sound basis for computing the quantity of each of a wide variety of fodders necessary for nutrition, and have thus rendered available the knowledge essential for the formulation of long range policies of drought feeding.

A great deal of work has also been done on pastures to determine the seasonal variations in nutritive value, the effect of different top-dressings, and the importance of particular species of pasture plants. The results of all these investigations have elucidated many factors of far-reaching importance to Australia's pastoral industry.

During the war the Division has been engaged on problems associated with the victualling of our armed Forces. Information upon which Service rations are now based was made available and many problems involving considerable research have been solved. The Division has extended its work to problems on the solution of which the improved nutrition of the people of Australia must largely depend.

The future of wool as a textile fibre depends not a little on its cost of production. Consequently one of the main post-war activities of the Division should lie in research concerned with nutritional problems of wool production.

5. Soils.

The intensification of farming under irrigation or by pasture development and the solution of problems of soil erosion and conservation call for studies of the soil so as to prepare a solid foundation for proper land use, the efficient exploitation of existing resources, and the further investigations concerning crop and animal production which may be required. The functions of the Soils Division are to survey, classify, and evaluate the soils of Australia and to carry out research into the chemical, physical, and bacteriological problems concerned with soil fertility and agricultural production.

In the Murray River settlements, all of which have now been surveyed, serious losses have been suffered through salting and seepage. The work of the Division has revealed the causes of these troubles and has disclosed methods by which they have largely been overcome.

In Tasmania the soils of the orchard areas and the pine plantations have been examined and surveys have been made of certain areas selected for consideration for post-war settlement. Following a proposal to reclaim Lake Albert, at the mouth of the Murray River, a survey was made of the lake bed in order to ascertain if the soil was suitable for dry farming or irrigation. The results showed that reclamation was not justified, and thus the expenditure of a very modest sum of money prevented what might have been a costly mistake in land settlement.

A survey in connection wtih soil erosion problems of a large area in the wheat belt of South Australia led to successful work by the State Department of Agriculture. Another survey for the purpose of securing information on problems relating to pine tree growth enabled both the State Government and private forestry companies effectively to extend the planting of soft-woods. A number of areas gazetted as irrigation districts have been surveyed, and the information thus obtained will greatly facilitate the proper planning and subdivision of the settlements and the efficient use of irrigation water.

The Division has rendered material assistance in connection with certain war problems. For example, important questions arose out of the decision to use soil-cement for the construction of aerodrome runways. A programme of investigation was undertaken and as a result the Division was able to give authoritative advice regarding site selection, methods of construction, &c. Similar investigations on dust nuisance and soil stability were conducted. As regards post-war activities, the immediate aim should be to survey all areas in Australia proposed for land settlement schemes, i.e., unless they are already being investigated by the States. It is well known that after the 1914-18 war serious mistakes were made in the planning of certain land settlement schemes. In many cases these mistakes were due in no small measure to a lack of knowledge of the soils.

6. Irrigation Settlements.

C.S.I.R. has two Irrigation Research Stations, one at Merbein, on the Murray River in Victoria, the other at Griffith, in the Murrumbidgee Irrigation Area, N.S. Wales. Both are situated in the midst of important irrigation settlements and maintain the closest touch with the settlers. Both Stations are really more than research centres; they are places to which the growers go for advice on matters connected with crops and irrigation. Moreover, full use is made by the State irrigation authorities of the knowledge gained from the work of the Stations. This has been reflected in marked improvement in irrigation practices, the initiation of communal drainage schemes, &c.

The Merbein Station has solved many problems associated with the irrigation of Murray soils, the preservation of soil fertility under irrigation, the horticultural procedure necessary to give maximum

returns, and the processing and preservation of the products. Investigations have been carried out into vineyard practices—pruning, tipping, cincturing, &c., methods of cultivation, and the use of fertilizers.

In the early years, Australia's raisins and sultanas were unsuitable for the overseas market as the dip used gave them too dark a colour. The Merbein Station evolved a dip which gave a uniform light colour, with the result that prior to the war, when export ceased, the Australian products competed successfully with those from other countries. Moreover, the production per acre in the old established areas has been more than doubled. Formerly, considerable losses were suffered through insect infestation of dried fruits, but this trouble has now been overcome by the use of a fumigant (ethyl formate).

The work of the Griffith Station has had profound effects in improving manurial and cultivation practices throughout the Murrumbidgee Irrigation Area. The Station has shown how serious damage by frosts can be obviated. It has discovered how the alternate cropping habit in Valencia oranges can be controlled. It is engaged in an extensive programme of work on problems concerned with the production of vegetables, for which the M.I.A. has become one of the most suitable irrigation centres. The investigations include irrigation techniques, fertilizer requirements, problems of seeding and germination, tillage and cultural problems, and weed control.

The war has proved that Australia's irrigation areas can produce large quantities of foodstuffs of a very wide range and that they are more reliable and valuable as food-producing centres than other districts. It is generally agreed that the new food industries developed in some of our irrigation areas during the war, and the expansion of pre-war production, have come to stay. Much research will have to be carried out in order to maintain the position. Though a great deal has been done for the irrigation areas adjacent to the two Stations, extension of similar work to other districts will be necessary owing to differences in soils, crops grown, and general environmental conditions.

7. Food Preservation.

Australia lies so far away from the main food importing countries of the world, and is itself a land of such long distances, that the preservation and transport of perishable products involve problems of great importance.

One of the more important problems tackled by the Division of Food Preservation and Transport before the war was the export of Australian beef in a chilled condition instead of frozen, so that it could compete with the chilled beef from South America. After a thorough scientific study of the processes of slaughtering, cooling and storage, methods were devised whereby chilled beef could be exported, despite voyage periods of up to 60 days. By 1939, the export of chilled beef had reached nearly 30,000 tons per annum, valued at £1,000,000.

As regards fruits, marked improvements have resulted from the Division's work in the cold storage of apples, pears, and oranges. The proper conditions for ripening bananas have been defined and the results adopted widely. Methods of controlling wastage in plums shipped to England have also been discovered.

Serious losses in Australian eggs exported to England or stored locally have often threatened the stability of a trade which in exports only was valued at more than £600,000 per annum prior to the outbreak of war. The Division found that the main causes of loss resided in the methods of handling and treating the eggs on the farms. As a result remedial measures have been devised for application in the post-war years.

The safe frozen storage life of a number of species of Australian fish and the conditions necessary to ensure a maximum period of holding in the frozen condition have been determined. The quality of some species of Australian smoked fish has been greatly improved.

Following the outbreak of war the Division's work was re-organized and problems not directly concerned with the war were abandoned. Much attention has now been given to problems associated with the dehydration and canning of foodstuffs. Surveys have been made of processing plants, the standards of quality improved, and production largely expanded. The Division has, in fact, played a most important part in assisting in the enormous extension of the canning industry during the war, particularly in vegetable and fruit-juice canning. Work on the efficiency of can making and closing and the lacquering of cans has been particularly successful. The Division has been able to give valuable assistance and advice in connection with the formulation of many specifications for processed foods.

The general objects of the Division's work will be unchanged in the post-war years. Most of the work now in progress or temporarily abandoned will have to be continued and intensified. The programme of work will depend to some extent on developments in the food industries in Australia and particularly on the trends in food exports.

It is evident that the Division can do and has already done a great deal not only to assist the development of an export trade in perishable foodstuffs, but also to increase efficiency in the food processing industries and maintain the highest possible quality standards for consumption in Australia.

8. Forest Products.

Australia has not utilized its timber wealth to anything like the best advantage. Valuable woods have been destroyed wholesale and we have paid enormous sums for imported timber. Until recent years, common practice in the timber-using industries in such matters as seasoning, milling, preservation, and gluing, was definitely bad, but this state of affairs has now largely been rectified as a result of the work of the Forest Products Division.

Following the development by the Division of kilns suited to our special requirements, the seasoning of Australian timbers is to-day of as high a standard as anywhere in the word; Australian timbers have now secured the popularity they deserve and are highly prized for their excellent properties.

Despite adverse reports by visiting paper-making authorities it has been shown that satisfactory paper can be made from eucalypts and this had led directly to the establishment of three large pulp and paper

mills costing several million pounds and employing some thousands of people. As a result cellulose pulp has been supplied for explosives and Australia has met its paper requirements during the war with a minimum of imports.

Work on the preservation of posts, poles, sleepers, &c., has proved of immense value. In the case of electric supply and telephone poles alone, every year that can be added to the life of existing poles means a saving of over £500,000 in replacements. Many years of life have been so added.

When defence requirements called for a tremendous development of large stores, hangars, &c., work done on the use of modern "connectors" provided the solution of the problems of quick erection and minimum consumption of timber. As buildings were erected further north the problems of protection against rot and termite attack became more and more serious. In the solution of these problems the Division's work on fungi and insects and on preventive measures came into very effective use. As the fighting moved into tropical areas the problems of proofing all classes of material against fungi became particularly important, and the Division has helped materially in solving this difficulty.

Much of the supplies required by the Services has to be transported in wooden boxes. The choice of suitable timbers and methods of construction became important, for the quantities of timber involved ran into hundreds of millions of feet. A large number of the boxes were redesigned, with consequent substantial savings in timber, manpower, and money cost. Studies of the properties of Australian timbers have played an important part in solving many other war supply problems.

The problem of making improved (compressed-impregnated) wood from Australian timbers has been overcome and very high-grade material produced. The Division has made blanks from which have been turned variable-density wood airscrew blades. The improved wood blade is lighter than the metal blade and has other advantages. The standard of gluing of plywood has been raised and veneer which was formerly burnt has been converted at negligible cost into the raw material for the manufacture of high-grade plywood immune to borer attack. Gluing problems associated with the manufacture of aircraft and a wide range of other products have been overcome. A serious shortage of safety match splints was averted by experimental work leading to the successful use of mountain ash for that purpose.

In addition to the above, the Division has handled innumerable inquiries and has investigated a host of problems, both of a wartime and peacetime nature, dealing with such things as rot-, insect-, and fire-proofing of timber, marine borers, aircraft timbers, laminated structures, gums and resins, cooperage, wood stave pipes and tanks. Looking back over the years, the results of the Division's work have paid for themselves many times in savings to the community.

There is a large field of work awaiting attention. Existing methods of conversion and utilization of timber are very wasteful. Of the fallen trees less than 20 per cent., on the average, is utilized. Short logs and off-cuts can produce high-grade material. Durable timbers are becoming increasingly scarce. New methods of impregnating timber

with resins, &c., and new plywood and veneer techniques must be developed. Sawdust, in conjunction with other forest wastes, must be regarded as a raw material for a wide range of useful products. There is an important field for research in the expansion of the manufacture of paper and pulp products such as building boards.

9. Fisheries.

Though it was not until shortly before the outbreak of war that the Fisheries Division was equipped actively to pursue its work, it has already obtained results of considerable value. The Division has concentrated its activities on problems directly related to the war effort. Members of the staff and facilities of the Division were made available to the Department of War Organization of Industry to establish an authority so as to secure during the war maximum fish and marine production with a minimum of manpower and equipment. As regards pelagic (surface-swimming) fish, data collected have already made it possible to form an estimate of the fishing results likely to be achieved in the areas explored. Pelagic fisheries in these areas are not likely to yield results comparable with those in certain well-known fishing grounds in other parts of the world, but there is a good prospect of substantial development. The aerial reconnaissance work carried out by the Division has attracted wide attention in other countries; this has been demonstrated as a practical means of increasing the effectiveness of fishing fleets and is a line of work which should be pursued vigorously after the war.

Agar, used for meat canning and bacteriological purposes, was supplied by Japan before the war. The Division has shown that certain Australian seaweeds can be used for the production of agar. Satisfactory methods of processing have been evolved and a new industry has been established.

Cessation of imports of cod-liver oil resulted in a serious deficiency of Vitamin A. The Division has shown that shark livers are rich in this vitamin and suitable processes for treatment and extraction of the oil have been devised. There is now in Australia a considerable industry in the production of Vitamin A concentrates of high quality. As a result of the Division's work a plant has been erected for the conversion of fish offal into fertilizer and oil. Marked improvements have been effected in methods of processing fish by smoking and canning.

As to the future, with respect to the scientific investigation of Australia's marine resources the fringe only has so far been touched. Work should be pursued to establish the commercial value of new trawling grounds. Methods of securing maximum yields and use of products such as oil, meal, and glandular extracts should be investigated. There is an important field of work requiring investigation in connection with the development of the oyster industry. The crayfish, crab, and scallop industries are capable of substantial development if the necessary exploratory and biological work were undertaken. The search for suitable seaweeds for the production of agar, Irish moss, and other products should be intensified. The reclamation of fish by-products and the use of inedible species of fish for producting fish meal for stock feed and oil for industrial use are important industries in other countries.

10. Dairy Products.

The war gave rise to some urgent problems of dairy manufacture, owing partly to the increased demand and to the special conditions which had to be met, e.g., with respect to supplies which would stand up to tropical conditions, and also to shortage of refrigerated shipping space.

The curtailment of supplies of New Zealand white pine previously used almost exclusively for butter boxes gave rise to a serious problem. Australian timbers imparted a marked taint to the butter. A cheap and effective process was evolved for eliminating the taint by spraying the boxes with a solution of casein and formalin. All butter exported from Australia during the last seven years has been packed in boxes treated by this process and wood taint is now a thing of the past.

Low-grade butter had accumulated in Australian cold stores as it could not be exported owing to shortage of refrigerated shipping space. A process was discovered whereby pure butterfat could be produced from the low-grade butter and exported without refrigeration, thus obviating serious losses.

Another urgent problem arose from the fact that butter melts and deteriorates rapidly under tropical conditions. Investigations resulted in the production of a " tropical butterfat spread ", which has a melting point 20°F. higher than that of butter and is not subject to bacterial deterioration.

The causes of loss of butterfat in churning have been investigated and methods evolved for reducing them to a minimum. A successful method has been developed for compressing milk powder into blocks, resulting in a substantial saving in both shipping space and containers. Improvements have been effected in the keeping quality of milk powders under tropical conditions.

After the war the dairying industry must meet increased competition and the importance of research to assist the industry and to improve its products is apparent. Much of the cheese made in Australia is of poor quality and after the war research should be undertaken so as to enable sound advice to be given on a number of problems in that connection. Research on improved methods of butter manufacture will be necessary if butter is to face the almost certain increased competition from margarine. In comparison with other countries with large dairying industries Australia has so far provided only small facilities for research.

11. National Standards.

Following the decision of the Commonwealth Government to extend the activities of C.S.I.R., approval was given in 1938 for the establishment of a National Standards Laboratory, of which the main functions would be to maintain the national reference standards of measurement for the Commonwealth and to calibrate sub-standards. The Laboratory was to be the Australian counterpart of national institutions in other countries, such as the National Physical Laboratory in England and the Bureau of Standards in the U.S. America. The main part of the Laboratory was completed early in 1940.

In the meantime war had broken out and this profoundly affected the work of the Laboratory: it was necessary to divert its activities from the original objectives and to concentrate attention on matters concerned with the application of standards and testing which became vitally urgent in connection with the war. There are three main Sections in the Laboratory, viz., (1) Metrology, (2) Physics, and (3) Electrotechnology.

The Metrology Section is concerned mainly with the production and calibration of gauges and other measuring instruments required for the manufacture of precision machinery and munitions. It has acted as the control centre in N.S. Wales for the wide network of Directorates and Inspection Departments responsible for the acceptance of equipment manufactured for the Services. It has also acted on behalf of the Directorate of Machine Tools and Gauges in sponsoring the manufacture of precision instruments such as slip gauges, pitch measuring machines, micrometers, and workshop projectors. Special measuring equipment essential for war purposes and not available from abroad has been designed and manufactured by the Section.

The requirements for munitions production and the needs of the Services during the war necessitated a rapid development in the work of the Physics Section. It has undertaken the testing and calibration of all temperature measuring equipment in munitions manufacturing establishments in N.S. Wales. It has rendered marked assistance in the manufacture of pyrometric equipment and in the field of low temperature work. In optics the Section has investigated a wide range of problems, including the supervision of the properties of optical glass manufactured in Australia, the methods of manufacture of searchlight and heliograph mirrors and of black-out materials, the examination of numerous optical munitions instruments, and the supervision of the optical properties of naval gun-sight telescopes. In photometry and colorimetry a wide range of problems has been solved for the Services.

The major work of the Electrotechnology Section has been associated with the development and manufacture in Australia of instruments required by the Department of the Army for the control of gun fire. The purpose of these instruments is to enable artillery to benefit from the use of radar. The Section has carried out the fundamental work required for degaussing ships as a protection against magnetic mines. It has undertaken the investigation of defects in design and materials used in electrical equipment so as to enable such equipment to withstand the rigours of a tropical climate.

12. Radiophysics.

The Radiophysics Laboratory was established at the beginning of the war to provide research facilities required by the Services for the development of radar equipment. The specific task of the Laboratory was to investigate the conditions of the Pacific war and the requirements of the Services and to design equipment specially suited for this theatre.

For security reasons particulars of the different types of equipment which were developed cannot be given. It may, however, be said that the special requirements of the Pacific theatre were fully understood by the Laboratory before the Japanese entered the war. As a result, it was possible, very soon after the Japanese began their offensive, for

the Laboratory to supply sets of air-warning equipment to the R.A.A.F. The equipment was readily transportable by air and as a result was installed very soon after the beginning of the war with Japan. Before the sets were installed fighter aircraft were incapable of meeting the Japanese attacks, but this situation completely changed with the provision of early warning, which enabled fighters to be got into the air and to be directed from the ground.

The equipping of aircraft with radar permits them to observe ships in any conditions of weather or at night and to launch offensive strikes in these conditions; it also provides exceptionally good navigational aid to the aircraft. Equipments of this nature were designed at the Laboratory and are now widely used by the R.A.A.F. as a result of production in Australia.

In addition to providing the research facilities resulting in the production of the various types of equipment, the Laboratory has given extensive assistance to the Services in the form of information on new methods for the use of radio equipment and in the instruction of Service personnel. Investigations on fading and other transmission problems have been conducted and have enabled the Council to provide the Services with information urgently required to improve the reliability of radio communication.

Two main conditions must be fulfilled if the phenomenal industrial development of Australia during the war is to be maintained. There must be adequate facilities within Australia for the maintenance of accurate measurements in engineering and physics; this need has been widely felt during the war and the facilities which have been provided for the purpose must be maintained and adapted to peace-time needs. The second condition is that Australia cannot, if our industries are to be developed effectively, afford to revert to the pre-war conditions under which we relied largely on scientific information from overseas. Adequate research facilities, accompanied by close liaison with industry, must be provided in Australia. A Commonwealth Standards and Physical Laboratory, utilizing the facilities developed at the National Standards and Radiophysics Laboratories, should form one of the chief organizations which could contribute to the fulfilment of these conditions.

13. Aeronautics.

The Aeronautical Laboratory has carried out a large amount of research and development work for the R.A.A.F., the Australian aircraft industry, the Department of Civil Aviation, and other authorities, in the design and testing of new types of aircraft and the improvement of existing types.

Species of Australian timbers suitable for various aircraft purposes have been found, design data worked out, and methods of fabrication devised. For example, wooden belly tanks for fuel—lighter, stronger, and cheaper than the metal tanks previously used—have been successfully developed, thus increasing the range of the aircraft. In the wind tunnel a great number of tests has been made to obtain information on the design of new types of aircraft. Numerous armament and parachute tests have also been made. Other miscellaneous tests cover

such diverse fields as the cooling of armoured fighting vehicles, the airflow in engine test houses and factories, and the design of plants for the dehydration of foodstuffs.

For one type of aircraft, special wings were developed and a new type of engine installation worked out so as to utilize a large part of the energy normally wasted in the engine exhaust. Tests of the engine installation of another type resulted in the appreciable extension of the operational range of the aircraft.

Examinations and tests have been made of Japanese aircraft engines, accessories, instruments, and other equipment. From these valuable information has been obtained on the performance of the enemy's aircraft, the strength and quality of the materials used, and the economic position regarding shortages of essential metals, &c. A special installation to exclude dust, which is the cause of rapid wear of aircraft engines in parts of Australia, has been developed. Investigations have been made into the reclamation of engine cylinders by chrome plating and it has been shown that the life of a reclaimed cylinder is equal at least to that of the original cylinder. A method has been devised for producing cylinders for air-cooled aero engines which does not involve expensive forging and machining operations and which permits of improved design. A considerable amount of testing and development work has been done on small engines used for Army and Air Force field generator sets. A service of considerable value has been rendered in the salvage of aircraft components and materials damaged by corrosion during storage or transport; this was of vital importance in the early stages of the war against Japan, when it was a crucial matter to maintain the small number of combat aircraft at our disposal in the highest degree of serviceability. A parachute has been devised and is now in large-scale production for use in dropping supplies from the air in such a way as to reduce the velocity of impact with the ground and thus prevent damage to the packages.

The post-war activities of the Laboratory must depend to some extent on the Government's policy in relation to the R.A.A.F. and the aircraft industry, but it is obvious that there must be a very important and wide field of work to be carried out by the Laboratory in peacetime.

14. Industrial Chemistry.

As this Division was not established until after war broke out, the problems investigated have been confined almost entirely to those of direct war importance; they have been concerned mainly with the development of methods for manufacturing from Australian raw materials products required for munitions and Service equipment. Although it is less than three years since the Division's laboratories were erected and equipped, some notable successes have already been achieved.

One of the first contributions to the war effort resulted from investigations leading to the formulation of specifications for charcoal for producer gas units. Work on foundry sands has been of great assistance to the munitions industry and its value will be equally great in the post-war period. Work on shrink-proofing of woollen goods required by the Services has led to the development of a process which is ready for commercial exploitation. Numerous investigations for the

Services and the aircraft industry include work on equipment for detecting magnetic mines, preventing deterioration in transparent plastic aircraft windows and aircraft cables, cleaning of internal combustion engines, prevention of mould growth on leather boots, and deterioration of gun-cotton bags.

Work on the utilization of the black sand deposits of Australia's eastern shores has been of great value to the war effort. Processes have been developed for producing from them materials for smokescreen (thus eliminating the necessity for importing large quantities of an expensive product), for an indispensable constituent of radio valves (thus averting a major breakdown in the radio valve industry), for the cores of searchlight carbons, and for a polishing powder which will save much time and effort in the production of optical equipment.

The Division has assisted in developing a process now used on a large scale for the production of potash fertilizers from Western Australian alunite; it has patented a new process for the recovery of chromium compounds urgently required by the electroplating, tanning, and paint industries; it has shown how Australian graphites can replace imported graphite in the production of dry cells required in huge quantities by the Services; and it is working on lithium and beryllium minerals with a view to their exploitation for important wartime needs.

The investigations of the Division have stimulated the interest of several Australian companies in the production of ethylene (derived from alcohol), and of furfural (from waste agricultural products), both used in the plastics and related industries. It has determined the data from which the gas industry can design plant for producing organic chemicals from tar oils of low value; it has worked out methods for preparing synthetic rat poisons required by the Army, and chemicals for essential drug production; it has developed synthetic resin adhesives necessary for producing improved wood for propellor blades and other purposes, and has assisted the plastics and adhesives industries in other ways.

The results of investigations into important problems concerned with the production and utilization of cement have already averted serious economic losses. Fellmongery investigations give promise of improvements which will decrease substantially the losses of skins, improve the products, use fewer men, and make conditions of employment more congenial. Valuable work has been done in developing substitute containers to conserve tinplate. A process has been evolved for the concentration by flotation of tin from its ores. Substitute solders have been developed. A great deal has been done in the way of advisory services, particularly in connection with the production of aluminium, the recovery of tin from tinplate scrap, and the synthesis of certain organic chemicals.

During wartime, urgent investigations with immediate prospects of utilizing the results have claimed precedence, but when the war ends it is important that work of a more fundamental character should be undertaken. There is a vast and, in fact, practically unlimited field of research demanding attention in connection with Australia's chemical industries. The Division has prepared comprehensive plans for post-war research.

15. Miscellaneous.

In addition to the above major lines of work, the Council is engaged in many other activities. It maintains a Scientific Liaison and Information Bureau which deals with a large number of inquiries covering a wide range of scientific and technical subjects. It has a Lubricants and Bearings Laboratory which has rendered signal service in elucidating a number of very important problems arising out of the war. It is engaged in ore-dressing and mineragraphic investigations undertaken originally for the benefit mainly of the gold-mining industry, but during the war extended to the strategic base metals and non-metallic minerals. It maintains Scientific Liaison Offices in London and Washington, and it has a Section of Mathematical Statistics to provide its investigators with advice as to the proper planning of experimental work and to assist in the analysis of experimental data.

16. Conclusion.

Though the direct monetary value of the Council's achievements cannot be stated, there is no doubt that it amounts to many millions of pounds. A great deal has been done to assist in the war effort and the value of the contributions thus made to national security is, of course, incapable of expression in terms of money. The review which has been given of the Council's work speaks for itself and is sufficiently impressive.

The conclusion to be drawn is that in order to ensure the material prosperity of the Commonwealth, or if regarded only from the point of view of a good national investment, scientific research should receive increased encouragement and support. Recent events, such as the development of radar and jet propulsion and the remarkable progress made in Australia in adapting our industrial efforts to meet war requirements, have led to a wide general appreciation of the dependence of our national welfare, and even our national security, on scientific research. It is, therefore, reasonable to expect that there will be a whole-hearted recognition by the Commonwealth and State Governments, as well as by industrial establishments and individuals, of the supreme importance of utilizing and developing in the fullest measure Australia's scientific resources, not only in C.S.I.R., but also in other Government research organizations, in our universities and technical colleges, and in industry generally.

The Control of Insect Pests in Victorian Bulk Wheat Depots.

*By Frank Wilson.**

Summary.

Wheat stored in Victorian bulk-wheat depots is subject to infestation by many of the common grain pests. Of these, *Rhizopertha dominica* is of outstanding importance. Infestation is very largely restricted to a thin layer of wheat, about one foot in depth, at the surface of the mound, but, as the infestation would spread over the whole surface, considerable damage would result if the infestations remained uncontrolled. By applying finely divided magnesite or dolomite to the surface of the mound the number of infestations arising can be greatly reduced. Control of the infestations which develop despite the dust barrier can be obtained by local surface-fumigation with carbon bisulphide or ethylene dichloride. This dust-cum-fumigation method has given good results in Victorian bulk-wheat depots.

1. Introduction.

In an earlier article (Wilson, 1945), an explanation was given for the restriction of insect infestation in bulk-wheat depots to the periphery of the mound. Here, the main features of insect infestation in Victorian depots will be described, and the measures taken to control the pests outlined. As the article is a summary of the chief aspects of the insect problem in bulk depots, no detailed data will be given, these being reserved for later publication.

2. The Character and Development of Infestations.

Many of the common grain pests are present in the Victorian bulk-wheat depots. The insects commonly found are *Rhizopertha dominica* F., *Calandra oryzae* L.,† *C. granaria* L., *Latheticus oryzae* Waterh., *Tribolium castaneum* Herbst, *Oryzaephilus surinamensis* L., and *Laemophloeus minutus* Oliv. Other species occur exceptionally.

The wheat placed in Victorian bulk depots during this war has been of low temperature and moisture content and has provided a physical environment unfavourable for the insect pests. The development of infestations is aided, however, by the changes induced by seasonal climatic influences in the temperature and moisture content of the

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† Only the small strain of *C. oryzae* occurs in Victorian wheat depots. The two strains have been described by Birch (1944).

surface layer of the wheat mound. The effects of these seasonal influences are greatly modified by the structure of the depot, which causes the wheat temperature and moisture content to differ in different parts, the temperature being highest at the crest of the wheat mound, and the moisture content greatest at the bottom of the wheat slopes. Consequently, insects which require a high minimum temperature for reproduction (e.g., *Rhizopertha*) tend to appear first at the crest of the wheat mound, and those with a high minimum moisture-content requirement (e.g., rice weevil) occur predominantly on the lower part of the wheat slopes. However, an established infestation is to some extent independent of climatic influences, for the metabolic heat and moisture liberated by the insects helps to maintain a sufficiently high temperature and moisture content for reproduction. (The question of the production of lethal combinations of temperature and moisture content has been dealt with in the article mentioned in the introduction.)

There is another, perhaps even more important, factor which promotes the development of infestations of the primary pests. As infestation by any insects raises the temperature of grain, wheat initially unsuitable for the development of a pest with a high minimum temperature requirement may be rendered suitable for it by prior infestation by insects with lower minimum temperature needs.

Experience has shown that *Tribolium castaneum* is usually the first insect to appear in Victorian depots, developing in dense colonies at the warmer parts of the wheat mound—usually at the crest. *Oryzaephilus,* too, is often present at this early stage. Later, *Laemophloeus,* then *Rhizopertha,* and finally *Latheticus* appear. During this development the wheat temperature rises considerably, and when the temperature reaches its maximum *Rhizopertha* and *Latheticus* together constitute practically 99 per cent. of the total insect population.

Rice weevil and granary weevil are usually rare in such infestations at the crest of the mound, but they are sometimes present in small numbers in the relatively cool wheat close to the wheat surface if the moisture-content has been increased sufficiently by climatic influences or by the other insects. At the bottom of the wheat slopes, where the moisture-content is generally higher, rice weevil (and sometimes granary weevil) takes a more prominent part in infestation, and may even predominate for some time over *Rhizopertha.*

Taking the Victorian depots as a whole, the predominant insects are, initially, *Tribolium castaneum,* and, at a later stage, *Rhizopertha* and *Latheticus.* Other pests may be locally and temporarily numerous but by comparison with *Rhizopertha* and *Latheticus* they are rare and of little importance. Also, though *Latheticus* may outnumber *Rhizopertha* in a mature infestation, the latter causes incomparably more damage and is by far the more serious pest.

It is certain that the observed succession in pests of bulk wheat is closely connected with the changes in temperature and moisture content produced by the insects. It is likely, however, that nutritional factors influence greatly the relative importance of the different species, and probably the great quantity of "flour" produced by *Rhizopertha* aids *Latheticus* to attain its high population densities.

Once an infestation is well established, it heats the adjacent uninfested wheat and is enabled to spread rapidly on a gradually enlarging front. Consequently, though the initial *Rhizopertha* infestations are prone to occur at the warmer parts of the wheat mound (at the crest and the upper part of the northern wheat slope), the infestations will rapidly spread over the whole surface if they are not brought under control.

The development of new infestations is especially likely to occur at those parts of the wheat mound where the roof-supporting poles pass into the wheat. Insects dispersing by flight commonly alight on these poles and move downwards into the wheat below. Consequently, the wheat in the vicinity of the poles receives an influx of migrating insects that is far greater than the average for the wheat surface as a whole.

The depth to which insects are to be found in infested wheat depends upon the age of the infestation. In the early stages, the insects occur to a depth of many feet, but this depth is gradually reduced until, after a few months, the great majority of the insects exist within one foot of the wheat surface and very few indeed occur below a depth of two feet. It is only in this top foot of the wheat mound that considerable damage is done by the insect pests.

3. Control of Insects by Mineral Dusts.

There are some objections to the use of mineral dusts for the control of insects in bulk-wheat depots. First, such dusts increase the angle of repose of grain, cause it to flow less readily, and reduce the rate at which it can be handled by the loading-out machinery. Secondly, they render the depot atmosphere abnormally dusty during loading-out operations. Thirdly—a factor of some importance to the commercial grain dealer—the "bloom" of wheat is impaired by the dust film adhering to it. Fourthly, dusted wheat, even after passing through a simple cleaning plant, retains some of the dust and may produce a dusty atmosphere when the wheat is unloaded at the mill.

All these points have some validity, but, when the main consideration is the control of insects in wheat which must be stored for years, they are of minor importance. The main objection is that dusted wheat produces a dusty atmosphere for the men handling the grain, but the extent to which this is so is debatable, for the handling of bulk wheat is usually a very dusty operation irrespective of whether or not the grain has been treated with mineral dusts. Nevertheless, it is clear that the amount of dust used should be kept at a minimum consonant with reasonable efficiency in weevil control.

The treatment of all the grain as it is placed in a bulk-wheat depot would require such vast quantities of dust and would so lower the loading-out rate and increase the dustiness of the atmosphere, that, given the existing machinery for handling wheat, no commercial wheat handler would countenance such a proposal. The principal problem in utilizing inert dusts for the control of wheat pests is, therefore, to determine how limited amounts of dusts can be most efficiently employed.

In the account of insect infestation in bulk-wheat depots given in the preceding section it was shown that the insects are principally located near the wheat surface and that infestations are begun by the dispersal of insects from existing infestations. This dispersal takes place almost entirely at or above the surface of the wheat mound. Consequently, fresh infestations (as distinct from lateral expansion of infested areas) are dependent upon the dispersing insects penetrating through the wheat surface. This fact provided the possibility of using mineral dusts as a barrier at the surface of the wheat mound to prevent the entry of insects into uninfested wheat. The amount of dust necessary for the provision of such a surface barrier is very small by comparison with the quantity required for the complete treatment of a bulk of wheat.

Large scale experiments (details of which will be published later) have shown that a surface dust-barrier greatly reduces the extent of infestation in a block of wheat. The barrier does not by any means prevent entirely the development of new infestations, nor is it capable of bringing under control, or preventing the expansion of, existing infestations. Its effect is limited to a restriction of the rate at which new infestations arise, and those which do develop must be dealt with by local fumigation. Nevertheless, the advantages conferred by a dust barrier are well worth having, for otherwise the amount of fumigation necessary in order to keep the insect pests under control would be far greater. That dust barriers are not more effective is not surprising, for it is known (Fitzgerald, 1944) that *Rhizopertha*, the principal insect in Victorian bulk-wheat depots, is more resistant to mineral dusts than are the other primary pests of wheat.

Dust barriers have been employed extensively in Victorian bulk-depots during the past two years. The dusts used are magnesite (from Tullamore, N.S.W.) and dolomite (from Coomadai, Vic.), these having been shown by Fitzgerald to be two of the best available materials. The magnesite is rather more effective, and probably dolomite will not be employed in future. The dust, which is finely divided (a high percentage will pass a 200-mesh sieve), is scattered by hand over the whole surface of the wheat-mound at the rate of 35 ounces per square yard. This is equivalent to dusting the top six inches of the wheat mound at a dosage of nearly 1 per cent. by weight of the wheat, and the amount of dust required for a whole depot is about 5 tons per million bushels of wheat held, though this varies somewhat according to the dimensions of the wheat-mound.

The practice has been to scatter three-fifths of the dust and rake this into the wheat, and then to apply the rest of the dust to the wheat surface without raking. However, the large-scale trials did not clearly indicate that raking had a beneficial effect, and probably the dust would be just as effective if the whole of the dust were simply scattered fairly uniformly, without raking, over the wheat surface to give a continuous dust barrier.

It has been found advisable to lay down a particularly thick dust barrier on the wheat surface adjacent to the roof-supporting poles, for, as was mentioned above, wheat in this position is subject to a particularly heavy influx of migrating insects.

The dosage of 35 ounces per square yard was chosen more or less arbitrarily. Large-scale experiment has shown that a heavier dust barrier would be still more effective, but, as the existing practice gives a reasonably good result, it is thought that the advantages of a bigger dosage might well be more than offset by an increase in the disadvantages, previously enumerated, inherent in the employment of mineral-dust barriers.

4. Local Surface Fumigation.

Infestations which develop despite the dust barrier can be eliminated by local surface fumigation, the fumigant being applied directly to the infested wheat surface by means of a watering can. For consistently good results the distribution of the fumigant must be reasonably even. After applying the fumigant, the treated wheat surface should, preferably, be covered by tarpaulins or some other airtight material (such as Sisalkraft) for a period of 24 hours.

A considerable number of tests with several fumigants have been carried out in the depots, and the main results are outlined below. The principal insect present in the natural infestations used for the tests was, of course, *Rhizopertha*. As the tests were intended to lead directly to practical fumigation work, the fumigants tested were chosen chiefly because they were available in large quantities.

(*i*) *Carbon Bisulphide.*

At a dosage of 16 fl.oz. per square yard of wheat surface, carbon bisulphide gives practically a 100 per cent. kill of the adults and immature stages of *Rhizopertha*. Its effect on the less important pests has not been so thoroughly investigated, though it is known that *Laemophloeus minutus* is highly resistant to it. However, at the above dosage, this fumigant has been used on a commercial scale in the Victorian depots for more than eighteen months and the results appear to have been uniformly satisfactory. As, during this period, it has been employed against heavy concentrations of all the usual pests, it may reasonably be assumed to give a good kill of any of them except probably *Laemophloeus*. This insect, however, is of minor importance.

It is unfortunate that carbon bisulphide carries explosion and health hazards, for it has given more consistent results than the ethylene dichloride mixtures mentioned below and is far cheaper. The use of gas masks and the usual precautions against the risk of explosion have prevented any serious results from the employment of this fumigant, but recently—particularly during the hotter weather—it has been largely superseded by the ethylene dichloride mixtures.

(*ii*) *Ethylene Dichloride and Carbon Tetrachloride.*

A proprietary fumigant consisting of a mixture of ethylene dichloride and carbon tetrachloride (in the proportion respectively of 3 : 1 by volume) was tested against a natural infestation in which *Rhizopertha* and *Latheticus* were the predominant insects. In this test practically a complete kill of the adults and immature stages of both insects was obtained when the fumigant was employed at 45 fl.oz. per square yard.

At this dosage, the mixture has been used extensively in Victorian bulk depots but reports indicate that its results are erratic, refumigation of an infested area being sometimes, if not often, necessary. Nevertheless, the use of this fumigant is being persisted in because of its low health hazard and explosion risk.

(iii) Ethylene Dichloride and Trichlorethylene.

Ethylene dichloride and trichlorethylene were mixed in the proportion (by volume) of 3 : 1 respectively. As one would expect from its composition, this mixture is about as toxic as the preceding fumigant, and tests have shown that at the same dosage (45 fl.oz. per square yard) it gives an equally high kill of the adult and immature stages of *Rhizopertha*. Its effects on the other pests have not been thoroughly investigated, but in one test it gave poor results against some of the secondary insects.

The fumigant has been used in the Victorian depots on a large scale, and reports indicate that it does not consistently give the excellent results which are apparently always given by carbon bisulphide. The small risk involved in the use of this mixture has been the chief reason for its continued use.

(iv) Ethyl Formate.

When employed at 16 fl.oz. per square yard, this fumigant gave practically a complete kill of adults and immature stages of *Rhizopertha*. It also gave about a 90 per cent. kill in *Latheticus* adults, but the larvae of this insect were more resistant.

Ethyl formate has not been, and is not likely to be, used on a large scale in the depots. It is somewhat less toxic than carbon bisulphide when employed under depot conditions, is almost as dangerous in explosion risk, and is much more expensive.

5. Efficiency of Control Measures.

The combined use of dust barriers and "surface-fumigation" during the past eighteen months or so has given good results in Victorian bulk depots, and the infestations have at no time been so very extensive that they have threatened to become entirely out of control. This is so, despite the fact that the methods were developed after a considerable amount of wheat had been stored, and that the fumigation work has frequently been delayed by an irregular supply of fumigant or the necessity to transfer men normally engaged on this work to more pressing tasks.

In applying this dust-cum-fumigation method, the following are the main factors making for good results:—

(i) The dust barrier should be applied as soon as the wheat has been placed in store.

(ii) The whole of the wheat surface should be systematically and thoroughly examined at monthly intervals, and the location of infestations of any insects noted.

(iii) The discovery of any infestations should be followed, without delay, by their fumigation. This is of importance for two reasons. First, the numbers of insects dispersing to other parts of the depot are kept at a minimum. Secondly, the temperature of wheat fumigated at an early stage of infestation falls rapidly to a normal level, but wheat heated to a great depth by a long-standing infestation falls to a normal temperature only after a very long period, and during this time it is more likely to become infested than is cooler wheat.

(iv) An adequate reserve of the fumigant should be maintained.

Given reasonable efficiency in these matters, and assuming the wheat to be of normally low moisture content and not unduly infested when placed in store, there is no reason to doubt that the application of the dust-cum-fumigation method will keep losses from insect pests in a bulk depot at a very low level even if the wheat be stored for several years.

6. Acknowledgments.

My thanks are due to the Australian Wheat Board for the facilities given for these investigations, and to the Grain Elevators Board of Victoria for aid rendered during the course of the work.

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Experiments on the Control of Cabbage Pests in North Queensland.

By T. Greaves *

Summary.

The results of two field experiments with cabbage pests, carried out in the Burdekin area, North Queensland, are given. The early crop used in the first experiment was attacked by the larvae of four species of moth, namely, *Hellula undalis* Fabr., *Heliothis armigera* Hubn., *Prodenia litura* Fabr., and *Crocidolomia binotalis* Zell. No aphids occurred.

The cabbage moth, *Plutella maculipennis* Curtis, and the green peach aphid, *Myzus persicae* Sulz., were the dominant insects affecting the later crop on which a second experiment was made.

In the first experiment, dusts containing D.D.T. (1 and 5 per cent.), lead arsenate (10 and 20 per cent.), and calcium arsenate (10 and 20 per cent.) and cryolite (40 per cent.), all gave very satisfactory control after four applications made at ten-day intervals. Magnesite, derris, and magnesite plus nicotine were significantly inferior to the D.D.T., lead arsenate, calcium arsenate, and cryolite dusts.

In the second experiment, the D.D.T. (1 and 5 per cent.) dusts were significantly better than all other treatments against the cabbage moth, *P. maculipennis*, and the green peach aphid, *M. persicae*. Against *M. persicae*, magnesite plus nicotine was significantly better than four timbo dusts containing 0·5 per cent. rotenone. These, in turn, were superior to cryolite (40 per cent.): all other treatments were inferior. Owing to the enormous aphid population on the crop, dusts that had no aphidical effect were removed from the plants by the movement of the aphids, and in this manner the larvae of *P. maculipennis* were protected from the dusts.

Derris and timbo dusts containing 0·5 per cent. rotenone and timbo containing 1 per cent. rotenone were ineffective against *H. armigera* and *P. litura*.

The combined results of the two experiments indicated that when used to dilute lead and calcium arsenate, the order of effectiveness of the diluents was "pyrophyllite," kaolin, and hydrated lime. The Australian "pyrophyllite" is a very easy dust to apply and flows very readily.

The local Burdekin lime is a cheap useful diluent for lead and calcium arsenate when superior diluents are in short supply.

1. Introduction.

Lead arsenate, nicotine sulphate, and derris were in short supply during the 1943-44 season, and there was little hope of an improvement in the supply position in 1944-45. Field and laboratory experiments were carried out on cabbage pests in Canberra to find suitable substitutes for these important insecticides, to discover the best diluent for use in dusts and to determine the minimum quantity of lead arsenate necessary for satisfactory control. The last point needed clarification because, although in the past equal parts of lead arsenate and lime had usually been recommended, there was some evidence that this formulation involved a waste of lead arsenate.

Investigations in New Zealand by Cottier (1939) showed that good control of the larvae of *Pieris rapae* L. was obtained in that country by using lead arsenate spray at the rate of 2 lb. per 100 gallons, or dusts containing 17 per cent. lead or calcium arsenate diluted with hydrated lime.

* An officer of the Division of Economic Entomology.

In the U.S.A., Hervey and Pearce (1942) and Turner (1943) showed that pyrophyllite (hydrated aluminium silicate) was a better diluent for lead arsenate than lime, talc, or kaolin. Deposits of pyrophyllite containing a mixture of pinite (hydrated potassium aluminium silicate) and siliceous pyrophyllite have recently been found in New South Wales. If this material gave results similar to U.S. pyrophyllite, a considerable saving of lead arsenate would result from its use as a diluent.

The field trials in Canberra indicated that:—

(i) Lead arsenate can be diluted to a greater degree than normally recommended.

(ii) Calcium arsenate is as effective as lead arsenate against the larvae of the cabbage moth.

(iii) Magnesite plus nicotine is a very good dust for use against larvae of the cabbage moth and the cabbage aphid, *Brevicoryne brassicae* (L.).

(iv) Derris diluted with pyrophyllite gave a greater kill than when mixed with other diluents, but the amount used per acre was greater than that of the other diluents because of the easy flowing qualities of the pyrophyllite.

In order to confirm these results, and to have additional information before the commencement of the 1944-45 season in southern Australia, the tests were continued in North Queensland during the winter of 1944. At this time, synthetic cryolite was being made in small quantities in Australia for the first time, and information on its use for the control of cabbage and other pests was urgently needed. Tests with this material were therefore included in the programme, as well as tests with D.D.T. (dichlordiphenyltrichlorethane), small quantities of which had been made available for preliminary investigations.

Two experiments were carried out: The first, with a crop sown just after the wet season, and the second, late in the growing season when cabbage moth and green peach aphid were present on the crop.

The rotenone dusts used in the first experiment were made up from derris containing 6 per cent. rotenone, while those of the second experiment and the final dust treatments before harvest were made from timbo containing 4 per cent. rotenone.

2. Field Experiments.

(i) *Experiment I.—April-July,* 1944.

A crop of "Succession" cabbages was sown on April 1, 1944, and planted out five weeks later. The seedlings were dusted twice in the seedbed with a combined lead arsenate—nicotine sulphate dust, and dipped in lead arsenate—nicotine sulphate solution when planted out. No other treatment was given from the time of planting until the first experimental dusting on June 13, 1944. All dusts were applied with a knapsack dust gun.

A design for six replications of each of 25 treatments was used, involving ten rows, each of approximately 200 cabbages. Owing to the death of some seedlings following transplanting, the number of plants in each plot varied, but the randomization of the blocks made

allowance for this variation. Cabbages were planted on each side of the experimental plot as buffers. The treatments were:—

1. Magnesite—1 cwt./acre.
2. Magnesite plus 6% nicotine sulphate—½ cwt./acre.
3. 20% lead arsenate plus hydrated lime—35 lb./acre.
4. 20% lead arsenate plus kaolin—35 lb./acre.
5. 20% lead arsenate plus pyrophyllite—35 lb./acre.
6. 20% calcium arsenate plus hydrated lime—35 lb./acre.
7. 20% calcium arsenate plus kaolin—35 lb./acre.
8. 20% calcium arsenate plus pyrophyllite—35 lb./acre.
9. 10% lead arsenate plus hydrated lime—35 lb./acre.
10. 10% lead arsenate plus kaolin—35 lb./acre.
11. 10% lead arsenate plus pyrophyllite—35 lb./acre.
12. 10% calcium arsenate plus hydrated lime—35 lb./acre.
13. 10% calcium arsenate plus kaolin—35 lb./acre.
14. 10% calcium arsenate plus pyrophyllite—35 lb./acre.
15. Derris 0·5% rotenone plus kaolin—35 lb./acre.
16. Derris 0·5% rotenone plus talc—35 lb./acre.
17. Derris 0·5% rotenone plus pyrophyllite—35 lb./acre.
18. Derris 0·5% rotenone plus magnesite—35 lb./acre.
19. D.D.T. 5% plus pyrophyllite—35 lb./acre.
20. D.D.T. 1% plus pyrophyllite—35 lb./acre.
21. Cryolite (synthetic) 40% plus kaolin—35 lb./acre.
22. Cryolite (synthetic) 40% plus talc—35 lb./acre.
23. Cryolite (synthetic) 40% plus pyrophyllite—35 lb./acre.

24 and 25. Untreated controls.

Four applications of the treatments were made, each at ten-day intervals. Rain fell eight hours after the second treatment was applied, but did not affect this treatment to any great extent. The crop was grown for seed, and this permitted the treatments to be made right through to maturity of the hearts.

At the time of the first application, June 13, 1944, the cabbages were severely attacked by larvae of the following species of moths:—

Hellula undalis (Fabr.), the cabbage centre grub;
Crocidolomia binotalis Zell., the cabbage cluster grub;
Prodenia litura Fabr., the common cluster grub;
Heliothis armigera Hubn., the corn earworm.

Larvae of the above insects were present on a variety of crops and weeds on the same farm during the period of the experiment. The attack by the cabbage centre grub was most severe on seedlings immediately after transplanting, while the corn earworm and the common cluster grub were particularly severe in their attack on hearted cabbages. Larvae of the cabbage moth, *Plutella maculipennis* Curtis, were rarely seen in this crop; early crops of cabbages in the Burdekin area are seldom affected by this species. No aphids were seen.

Each cabbage was rated for insect damage by a system described by Hervey (1943) and adapted to suit local conditions. Ratings were made before any treatment was applied, and again after each treatment. The final ratings were made ten days after the last treatment.

Rating values used were:—

0 = clean, no leaves eaten.
1 = a little attack, but not enough to affect the market value.
2 = eaten enough to affect market value.
3 = badly eaten, a second-grade cabbage.
4 = destroyed, of no market value.

Where attack by cabbage centre grub in the seedling stage had caused multiple growth in the head, the plant was pruned back to leave only one head for final rating; otherwise the dusting of a multiple head would require a larger amount of dust for treatment and yield an uneconomic cabbage.

It was not possible to obtain weights of harvested cabbages because the crop was grown for seed.

Table 1 shows the results obtained under each treatment using the figure for the final rating only.

TABLE 1.—EFFECTIVENESS OF DUSTS AGAINST LEPIDOPTEROUS LARVAE ATTACKING CABBAGES AT HOME HILL, NORTH QUEENSLAND.—RESULTS OF EXPERIMENT I., APRIL–JULY, 1944.

Treatment.	Rate Applied.	Final Ratings after Four Dustings. Mean of Six Replications.	Mean Square Root Transformation Values.	Significant Difference at 5 per cent Level.
	lb. per acre			
5. 20 per cent. lead arsenate + pyrophyllite	36	0·08	0·22	
19. D.D.T. 5 per cent. + pyrophyllite	36	0·17	0·27	
20. D.D.T. 1 per cent. + pyrophyllite	35·5	0·14	0·31	
4. 20 per cent. lead arsenate + kaolin	38	0·11	0·32	
6. 20 per cent. calcium arsenate + lime	35·5	0·17	0·36	
7. 20 per cent. calcium arsenate + kaolin	35·5	0·14	0·37	No significant difference
8. 20 per cent. calcium arsenate + pyrophyllite	37	0·15	0·38	
14. 10 per cent. calcium arsenate + pyrophyllite	36	0·19	0·40	
22. Cryolite 40 per cent. + talc	34	0·22	0·40	
23. Cryolite 40 per cent. + pyrophyllite	32	0·17	0·41	
3. 20 per cent lead arsenate + lime	39	0·25	0·44	
13. 10 per cent. calcium arsenate + kaolin	35	0·27	0·51	Worse than No. 5
9. 10 per cent. lead arsenate + lime	38	0·30	0·53	Worse than No. 19 and preceding treatment
21. Cryolite 40 per cent. + kaolin	34	0·32	0·53	
11. 10 per cent. lead arsenate + pyrophyllite	37	0·31	0·55	
10. 10 per cent. lead arsenate + kaolin	34	0·32	0·55	
12. 10 per cent. calcium arsenate + lime	36·5	0·33	0·57	Worse than No. 4 and preceding treatments
2. Magnesite + 6 per cent. nicotine sulphate	55	0·54	0·72	Worse than No. 3 and preceding treatments
18. Derris* + magnesite ..	38	0·73	0·85	Worse than No. 12 and preceding treatments
16. Derris + talc	43	0·77	0·86	
17. Derris + pyrophyllite ..	39	0·99	0·99	Worse than No. 2 and preceding treatments
1. Magnesite	100	1·09	1·03	
15. Derris + kaolin	36	1·11	1·05	
24. Untreated Controls	..	1·93	1·37	Worse than all treatments
25. Untreated Controls	..	1·89	1·38	

Minimum difference between totals necessary for significance at— 5 per cent. level = ·24; 1 per cent. level = ·32; 0·1 per cent. level = ·41

* Derris used contained 6 per cent. rotenone—mixture used was 1 part derris 11 parts diluent = 0·5 per cent. rotenone.

(ii) *Experiment II.—July-October,* 1944.

For the second experiment seedlings of "Vanguard" cabbage sown on July 4, 1944, were planted out on August 11.

A design for 30 treatments and five replications was used involving a total of 150 small plots, each with nine to fifteen cabbages—an average of eleven for each plot. There were fifteen rows of cabbages in this trial, and the plot was bounded on each side by buffer rows of green broccoli because of the shortage of "Vanguard" seedlings.

Hydrated lime and kaolin, for diluting lead arsenate, were unobtainable by growers in the Burdekin area during the 1944 growing season, due to transport difficulties. Large deposits of lime occur naturally in the area, however, and in order to make preliminary tests of the local product, four additional treatments were included in the second experiment, using local lime as a diluent for the 20 per cent. and 10 per cent. lead arsenate and 20 per cent. and 10 per cent. calcium arsenate dusts. An additional untreated control plot was also added, bringing the total treatments in this experiment to 30. In the absence of very fine screens for sieving the Burdekin lime, a 60-mesh to the inch copper gauze sieve was used.

The planting out of the seedlings coincided with a population build-up of the green peach aphid, *M. persicae,* on a crop of 3½ acres of Chinese cabbage a few hundred yards on the windward side of the cabbage crop. There was a mass migration of the winged aphids on to the cabbage plot a few days after transplanting, and the crop was soon so heavily infested that the question of abandoning the trial was seriously considered because it was known that calcium arsenate and, to a lesser extent, lead arsenate would encourage the growth of the aphid population (Folsom, 1927). However, the necessity for the evaluation of D.D.T. and synthetic cryolite against the green peach aphid warranted a continuation of the experiment.

The seedlings were dipped in lead arsenate and nicotine sulphate solution when planted out, and the first experimental dusting was carried out six days later. Nevertheless, the cabbage centre grub, *H. undalis,* caused some damage to the transplanted seedlings in their early stages.

Attack by the cabbage moth, *P. maculipennis,* was very severe in this crop, and outweighed all other larval attack on the plants. At the hearting stage, the corn earworm, *H. armigera,* and the common cluster grub, *P. litura,* were also present. Mass attack by the cabbage cluster grub (*C. binotalis*) occurred on the control plants, but not on any of the treated plants.

Four applications of dusts were made, the first six days after planting out and the other three applications at ten-day intervals. The plants were rated for attack by moth and aphids ten days after the fourth application. When rating was completed, the whole crop of cabbages was dusted with a timbo 1 per cent. rotenone dust, with kaolin as the diluent, and this treatment was repeated at weekly intervals until the crop was harvested on October 24.

Ratings for damage by leaf-eating larvae were based on the same standards as in Experiment 1. The ratings for aphids were:—

0 = no aphids.

1 = aphids present.

2 = two or more leaves affected by aphids.

3 = plant badly affected by aphids.

4 = destroyed, of no market value.

On analysis of the results, the rating figure of 1 proved unsatisfactory because incipient colonies of aphids could be found under the lower leaves of all plants, although the number of colonies varied from treatment to treatment; only one cabbage in the whole plot was entirely free from aphids.

Table 2 shows the final rating figures for attack by leaf-eating larvae, and Table 3 the corresponding ratings for green peach aphid. Table 4 shows the weight of cabbage heads actually marketed in October.

TABLE 2.—EFFECTIVENESS OF DUSTS AGAINST LEPIDOPTEROUS LARVAE (CHIEFLY *Plutella maculipennis*) ATTACKING CABBAGES AT HOME HILL, NORTH QUEENSLAND.—RESULTS OF EXPERIMENT II., JULY–OCTOBER, 1944.

Treatment.	Rate Applied.	Final Ratings after Four Dustings. Mean of Five Replications.	Significant Difference at 5 per cent. Level.*
	lb. per acre		
25. 5 per cent. D.D.T. + pyrophyllite ..	32	0·62	
26. 1 per cent. D.D.T. + pyrophyllite ..	30	0·80	
27. Cryolite 40 per cent. + kaolin	29·5	1·98	Worse than No. 26 and preceding treatment
29. Cryolite 40 per cent + pyrophyllite ..	44	2·72	Worse than No. 27 and preceding treatment
28. Cryolite 40 per cent. + talc	30·5	2·90	
6. 20 per cent. lead arsenate + pyrophyllite	38	3·02	
20. Timbo 0·5 per cent. rotenone + kaolin	38	3·04	
8. 20 per cent. calcium arsenate + Burdekin lime	37·5	3·12	
21. Timbo 0·5 per cent. + talc	38	3·12	
4. 20 per cent. lead arsenate + Burdekin lime	37	3·24	Worse than No. 29 and preceding treatments
22. Timbo 0·5 per cent. + pyrophyllite ..	38	3·24	
23. Timbo 0·5 per cent. + magnesite ..	35·5	3·28	
10. 20 per cent. calcium arsenate + pyrophyllite	18	3·38	Worse than No. 20 and preceding treatments
2. Magnesite + 6 per cent. nicotine sulphate	51·5	3·54	Worse than No. 21 and preceding treatments
5. 20 per cent. lead arsenate + kaolin ..	26	3·54	
13. 10 per cent. lead arsenate + Burdekin lime	50·5	3·54	
9. 20 per cent. calcium arsenate + kaolin..	22·5	3·64	Worse than No. 10 and preceding treatments
3. 20 per cent. lead arsenate + hydrated lime	26·5	3·70	
17. 10 per cent. calcium arsenate + Burdekin lime	50·5	3·70	
15. 10 per cent. lead arsenate + pyrophyllite	36·5	3·72	
7. 20 per cent. calcium arsenate + hydrated lime	24·5	3·74	Worse than No. 13 and preceding treatments
18. 10 per cent. calcium arsenate + kaolin..	27	3·74	
14. 10 per cent. lead arsenate + kaolin ..	27·5	3·76	
19. 10 per cent. calcium arsenate + pyrophyllite	33·5	3·78	Worse than No. 17 and preceding treatments
12. 10 per cent. lead arsenate + hydrated lime	28	3·86	Worse than No. 19 and preceding treatments
1. Magnesite	37·5	3·90	
16. 10 per cent. calcium arsenate + hydrated lime	26	3·90	
11. Untreated Controls	..	4·00	Worse than all treatments
24. Untreated Controls	..	4·00	Worse than all treatments
30. Untreated Controls	..	4·00	Worse than all treatments

* See discussion on analysis of results.

Table 3.—Effectiveness of Dusts Against the Green Peach Aphid on Cabbages at Home Hill, North Queensland.—Results of Experiment II., July–October, 1944.*

Treatment.	Final Ratings. Mean of Five Replications.	Significant Difference at 5 per cent. Level.§
25. 5 per cent. D.D.T. + pyrophyllite	1·00†	
26. 1 per cent. D.D.T. + pyrophyllite	1·02‡	
2. Magnesite + 6 per cent. nicotine sulphate ..	1·04	
22. Timbo 0·5 per cent. rotenone + pyrophyllite ..	1·20	Worse than No. 2 and preceding treatments
23. Timbo 0·5 per cent. + magnesite	1·22	
21. Timbo 0·5 per cent. + talc	1·40	
20. Timbo 0·5 per cent. + kaolin	1·50	Worse than No. 23 and preceding treatments
27. Cryolite 40 per cent. + kaolin	1·88	Worse than No. 21 and preceding treatments
28. Cryolite 40 per cent. + talc	1·94	
29. Cryolite 40 per cent. + pyrophyllite	2·78	Worse than No. 28 and preceding treatments
6. 20 per cent. lead arsenate + pyrophyllite ..	3·34	Worse than No. 29 and preceding treatments
4. 20 per cent. lead arsenate + Burdekin lime ..	3·44	
8. 20 per cent. calcium arsenate + Burdekin lime ..	3·72	
10. 20 per cent. calcium arsenate + pyrophyllite ..	3·74	
13. 10 per cent. lead arsenate + Burdekin lime ..	3·82	Worse than No. 6 and preceding treatments
5. 20 per cent. lead arsenate + kaolin	3·86	Worse than No. 4 and preceding treatments
15. 10 per cent. lead arsenate + pyrophyllite ..	3·86	
14. 10 per cent. lead arsenate + kaolin	3·88	
3. 20 per cent. lead arsenate + hydrated lime ..	3·92	
7. 20 per cent. calcium arsenate + hydrated lime ..	3·92	
9. 20 per cent. calcium arsenate + kaolin	3·94	
18. 10 per cent. calcium arsenate + kaolin	3·94	
1. Magnesite	3·96	Worse than No. 10 and preceding treatments
17. 10 per cent. calcium arsenate + Burdekin lime ..	3·96	
19. 10 per cent. calcium arsenate + pyrophyllite ..	3·96	
12. 10 per cent. lead arsenate + hydrated lime ..	4·00	
16. 10 per cent. calcium arsenate + hydrated lime ..	4·00	
11. Untreated Controls	4·00	
24. Untreated Controls	4·00	
30. Untreated Controls	4·00	

* Amount of dust per acre as in Table 2.
† Incipient colonies consisting of a few individuals only.
‡ Mostly incipient colonies consisting of a few individuals only.
§ See discussion on analysis of results.

3. Discussion.

The results of the first experiment, Table 1, show that D.D.T. (1 and 5 per cent.), lead arsenate (20 per cent.), calcium arsenate (20 per cent.), and cryolite (40 per cent.), applied at the rate of approximately 35 lb. per acre, gave nearly complete control: There was no significant difference between them.

The difference between the 10 and 20 per cent. arsenates was not significant. The derris dusts (0·5 per cent. rotenone) were all significantly worse than the D.D.T. lead arsenate, calcium arsenate, and cryolite treatments. Magnesite plus nicotine sulphate, applied at the rate of 56 lb. to the acre, was significantly better than derris diluted with talc, kaolin, or pyrophyllite.

In the first experiment, the D.D.T. dusts were made the final dusts to be put through one of the knapsack dust guns, and after each application of dusts, the dust guns were used for normal routine insecticidal work on the farm during the ten-day intervals between treatments. Difficulties due to suspected residual toxicity of D.D.T. in the second field trial are mentioned below.

TABLE 4.—GROSS EFFECTIVENESS OF DUSTS AS ESTIMATED BY THE WEIGHT OF CABBAGES HARVESTED FOR MARKET FROM PLOT USED FOR EXPERIMENT II. AFTER THREE DUSTINGS WITH A 1 PER CENT. EXPERIMENT II., JULY–OCTOBER, 1944.*

Treatment.	Weight of Heads.	Total of Square Root Transformation Values.	Significant Difference at 5 per cent. Level.
	lb.		
26. 1 per cent. D.D.T. + pyrophyllite ..	161	28·3	
25. 5 per cent. D.D.T. + pyrophyllite ..	172	27·9	
28. Cryolite 40 per cent. + talc	118	24·3	
27. Cryolite 40 per cent. + kaolin ..	101	21·7	
29. Cryolite 40 per cent. + pyrophyllite ..	81	17·6	Worse than No. 25 and preceding treatment
4. 20 per cent. lead arsenate + Burdekin lime	56	15·9	
6. 20 per cent. lead arsenate + pyrophyllite	51	12·9	Worse than No. 28 and preceding treatments
2. Magnesite + 6 per cent. nicotine sulphate	23	12·1	Worse than No. 27 and preceding treatments
8. 20 per cent. calcium arsenate + Burdekin lime	42	10·8	
10. 20 per cent. calcium arsenate + pyrophyllite	28	8·5	Worse than No. 29 and preceding treatments
21. Timbo 0·5 per cent. rotenone + talc ..	24	8·4	
3. 20 per cent. lead arsenate + hydrated lime	32	7·3	
7. 20 per cent. calcium arsenate + hydrated lime	19	7·1	
22. Timbo 0·5 per cent. + pyrophyllite ..	15	6·7	
5. 20 per cent. lead arsenate + kaolin ..	15	6·5	Worse than No. 4 and preceding treatments
13. 10 per cent lead arsenate + Burdekin lime	14	6·4	
20. Timbo 0·5 per cent. + kaolin	16	5·7	
18. 10 per cent. calcium arsenate + kaolin..	24	4·9	
23. Timbo 0·5 per cent. + magnesite ..	11	4·7	
14. 10 per cent. lead arsenate + kaolin ..	8	3·9	Worse than No. 6 and preceding treatments
17. 10 per cent. calcium arsenate + Burdekin lime	7	2·6	Worse than No. 2 and preceding treatments
15. 10 per cent. lead arsenate + pyrophyllite	5	2·2	
19. 10 per cent. calcium arsenate + pyrophyllite	5	2·2	
9. 20 per cent. calcium arsenate + kaolin..	4	2·0	
16. 10 per cent. calcium arsenate + hydrated lime	3	1·7	
1. Magnesite	2	1·4	
12. 10 per cent. lead arsenate + hydrated lime	0	..	
11. Untreated Controls	0	..	
24. Untreated Controls	0	..	
30. Untreated Controls	0	..	

Minimum significant difference between totals of transformation values, excluding control, at—

5 per cent. level = 8·94.
1 per cent. level = 11·88.
0·1 per cent. level = 15·31.

In the second experiment, there was no evidence of a difference in moth or aphid ratings as between blocks, but there was a marked variation between the mean ratings of the treatments and in the variability of replicates about the means. The relations between mean and variance for both the moth and aphid ratings are analogous to p and variance of p in the binomial distribution, except that the curves were asymmetrical and the maximum values of the variance did not occur at the centre of the rating scale. It would be possible, by use of a special transformation, to reduce the variability between replicates of the different treatments to approximately the same value, and then proceed as usual with the analysis of variance. However, it was simpler to produce a graph showing the minimum difference between a particular value and the higher or lower values for significance at 5 per cent. These minimum differences were computed by an iterative method. In the first experiment when all the treatment ratings were confined to one end of the rating range the square root transformation was adequate. This point has been dealt with by Bartlett (1936).

For simplicity in presentation, the treatments have been entered in the tables in the order of their ratings. Pairs of treatments whose differences are significant at the 5 per cent. level at least are indicated; the difference beween the lower member of the pair and any treatment with a higher rating than the higher member of the pair is obviously more significant, as is the difference between the higher member of the pair and any treatment rating lower than the lower member of the pair.

The aphid rating of 1 in the D.D.T. treatments did not represent the true status of the infestation by these insects. Incipient colonies, each of a few individuals, were found on nearly all plants, but the number found on the 1 per cent. D.D.T. treated plants exceeded those found on the 5 per cent. D.D.T.

The D.D.T. treatments were outstanding with respect to moth and to aphid infestation when the final ratings were made. The three subsequent treatments, using a timbo dust containing 1 per cent. rotenone, were applied after hearting, and coincided with a reappearance of *H. armigera* and *P. litura*. Had it not been for the damage caused by these species after the D.D.T. treatments had been discontinued, a still greater yield could have been expected from the plots treated with D.D.T. Table 4 shows the actual weight of cabbage heads harvested from the plot used for Experiment II.; most of the cabbages affected by cabbage moth or aphids at the conclusion of the test period did not recover when dusted with the 1 per cent. rotenone dust and were valueless for market purposes.

A residual effect of the D.D.T. dusts was suspected in the second experiment. The cryolite dusts followed the D.D.T. through the dust guns at each application of dust treatments; cryolite plus kaolin always followed the 5 per cent. D.D.T. dust, and cryolite plus talc always followed the 1 per cent. D.D.T. dust. In each case the cryolite plus kaolin dusts were more effective than cryolite plus pyrophyllite, although pyrophyllite normally is slightly superior to kaolin and talc as a diluent. In future comparative work, it will be advisable to apply D.D.T. from a separate dust gun.

The descending order of merit for the control of leaf-eating moth larvae, mainly cabbage moth, was D.D.T. (5 and 1 per cent.), cryolite (40 per cent.), lead arsenate (20 per cent.) in pyrophyllite, timbo (0·5 per cent. rotenone), lead arsenate (20 per cent.) in Burdekin lime, calcium arsenate (20 per cent.) in pyrophyllite, and magnesite plus nicotine sulphate. The remaining treatments gave little protection. The heavy nature and coarser particles of the Burdekin lime gave a heavier deposit (see Table 2), and enhanced its value in the 10 per cent. treatments.

The descending order of merit for the control of green peach aphid was: D.D.T., magnesite plus nicotine sulphate, timbo (0·5 per cent. rotenone), and cryolite. The remainder were all significantly worse. Timbo and magnesite plus nicotine sulphate dusts were effective against the green peach aphid, but gave little control of the cabbage moth in the second experiment.

One of the major purposes of these experiments was to obtain evidence on the relative efficacy of the various diluents used in conjunction with the different insecticides. In the two experiments, the

differences between treatments which varied only in the diluent used were, with few exceptions, not significant. However, there was evidence of consistent trends in these differences between related treatments.

Considering the 20 and 10 per cent. concentrations of the lead and calcium arsenates as a group, the mean difference in the first experiment between the transformed ratings for the pyrophyllite and kaolin was ·051 which was not significant; neither was the mean difference of ·086 between the pyrophyllite and lime diluents. In the second experiment the differences between the ratings for damage by lepidopterous larvae, using pyrophyllite and kaolin diluents, were significant at the 5 per cent. level for both 20 per cent. lead and calcium arsenates, but there was practically no difference between the ratings for the 10 per cent. dusts. Taking the arsenates as a whole, the weighted mean of the differences (the weight of each difference being inversely proportional to its error variance) for the diluents is not significant; on the other hand, the weighted mean difference of ·218 between pyrophyllite and hydrated lime is highly significant. The two experiments in conjunction indicated that with arsenates the order of effectiveness of the diluents was pyrophyllite, kaolin and hydrated lime. The relative worth of Burdekin lime is difficult to assess, because in the 10 per cent. treatments the density of arsenic applied with this diluent greatly exceeded other diluents. The relative effectiveness of the diluents used with the arsenate treatments are in the same order against the green peach aphid as against the lepidopterous larvae.

With respect to the insecticides other than arsenates, the relative order of effectiveness of the diluents in the first experiment with cryolite was talc, pyrophyllite, and kaolin, and with derris was magnesite, talc, pyrophyllite, and kaolin. In the second experiment the only diluent of cryolite likely to be free of contamination by residual D.D.T. in the dust gun was pyrophyllite. With timbo, the order of diluents is kaolin, talc, pyrophyllite, and magnesite. Taking timbo and derris in conjunction, there is nothing definite in favour of any particular diluent against lepidopterous larvae. Against the green peach aphid kaolin is significantly worse than pyrophyllite.

Because of the extreme variation in size of the cabbages in the second experiment, the amount of dust applied varied, but in all cases a dust film as equal as possible to that applied in the first trial was attempted, irrespective of size of plant. However, in the final application of dust, when only a small amount of dust was left to complete the work, the dust tended to flop out and cause irregular heavy deposits to be blown on to individual cabbages, increasing the figure for amount applied per acre. It was later discovered that a good head of dust in the dust gun is essential for the discharge of an even flow of dust from the type of gun used, particularly in the use of easy-flowing dusts such as pyrophyllite and talc.

The difference in ease of flow of the various diluents from the dust guns was obvious to the operators; pyrophyllite and talc flowed most easily, kaolin flowed less easily and hydrated lime needed a greater number of pumps each with greater pressure to put out the desired amount per acre. The addition of nicotine sulphate to magnesite retarded the flow of the magnesite, and the combined dust was very hard to apply.

4. Acknowledgments.

The above investigation was carried out on the Commonwealth Vegetable Farm at Home Hill, North Queensland, in co-operation with the Department of Commerce and Agriculture and the Queensland Department of Agriculture and Stock. I wish to express my deep appreciation of the assistance and advice given to me by the Farm Manager, Mr. F. W. Hely, Messrs. G. Rasmussen and G. Fowler of the farm staff, and Mr. N. E. H. Caldwell of the Queensland Department of Agriculture and Stock.

Thanks are also due to Mr. G. A. H. Helson, under whose direction the investigation was carried out, for suggestions and criticisms, to Mr. G. A. McIntyre, who was responsible for the field design, and for the statistical analysis of the results, and also to Mr. R. F. Powning for the analyses for rotenone content of the derris and timbo dusts.

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The Analysis of D.D.T. and Pyrethrins in Kerosene-based Sprays.

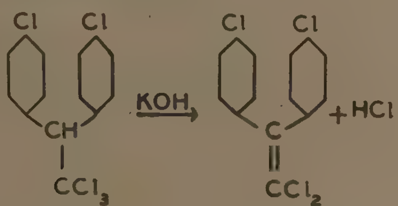
*By R. F Powning, A.S.T.C.**

Summary.

A method developed for the separation and analysis of D.D.T. and pyrethrins in a mixed insecticide spray is described.

1. Introduction.

D.D.T. or 2,2-bis(p-chlorphenyl)-1,1,1-trichlorethane has the typical chlorinated paraffin configuration which lends itself to dehydrohalogenation yielding an olefin type compound and hydrogen chloride. The chloride may be determined by a silver nitrate titration. The work of Zeidler (1874) showed that when D.D.T. was boiled in alcoholic KOH the molecule was dehydrochlorinated. The reaction is as follows:—



Compound 1 Dichlordiphenyltrichlorethane. Compound 2 Dichlordiphenyldichlorethylene.

The pigments and other substances in the pyrethrin extract interfere with the silver nitrate titration, so a column of alumina, as used in Tswett's chromatographic technique (Zechmeister and Cholnoky, 1941), is used to adsorb and separate them from the kerosene and D.D.T. In this way the D.D.T. is obtained as a clear solution in kerosene, and the pyrethrins are retained on the alumina, from which they may be recovered in a concentrated form for analysis. Since this method was developed a similar technique for the analysis of the D.D.T. component has been described in overseas reports.

2. Procedure.

(i) *Separation on Alumina.*

The method below is suitable for a 0·5 per cent. solution of D.D.T. with 0·03 per cent. pyrethrins. For pyrethrin analysis it is desirable to have at least 100 mg. pyrethrins in the sample, so with the solution above, a 400 cc. sample is required and a column of alumina 18 cm. by 3 cm. diameter (see Section 3).

(*a*) Add 400 cc. of the test solution gradually to the upper portion of the adsorption tube, and apply gentle suction so that it passes through the column and is collected in a 500 cc. conical flask. Reserve 50 cc. of this filtrate for subsequent D.D.T. analysis.

* An officer of the Division of Economic Entomology.

(*b*) When most of the sample has passed through, one lot of 20 cc. and a second of 80 cc. petroleum ether are added as a wash to remove the kerosene. Air is excluded from the column by always keeping a layer of the solvent above the alumina in these stages of the analysis.

(ii) *Pyrethrins.*

(*a*) Change the flask beneath the column after washing with petroleum ether, and elute the pyrethrins and pigments by drawing through about 300 cc. of 10 per cent. ethyl alcohol in petroleum ether.

(*b*) Reduce the volume to about 50 cc.

(*c*) Carry out the usual pyrethrin analysis on the residue.

(iii) *D.D.T.*

(*a*) To the 50 cc. sample, reserved in section (i) (*a*) of procedure, contained in a 250 cc. conical flask, add 25 cc. of approximately N/20 ethyl alcoholic potassium hydroxide, and boil under reflux for half an hour.

(*b*) When cool transfer contents of flask to a separating funnel. Wash the kerosene-alcohol mixture with six lots of 15 cc. distilled water, using the first two or three to rinse the flask. Each lot of water is then in turn shaken with 50 cc. petroleum ether in a second funnel.

(*c*) Bulk the aqueous extracts in a 250 cc. conical beaker and evaporate the alcohol and any petroleum ether remaining. Reduce the volume to about 40 cc.

(*d*) Cool and neutralize to phenolphthalein with N/10 sulphuric acid. Add ten drops of 0·1 per cent. dichlorfluorescein indicator (Kolthoff and Sandell, 1936), and titrate the chloride with standard silver nitrate solution to the usual pink end-point.

When it is only desired to determine the D.D.T. in the sample, a column of alumina 1·8 cm. diameter and 5 cm. long is sufficient. 75 cc. of the solution are drawn through and an aliquot of 50 cc. taken from the filtrate for analysis as above. A blank should be done on an equal quantity of kerosene treated as above as a check on reagents.

3. Apparatus and Reagents.

(i) *Standard Silver Nitrate Solution.*

Dissolve 4·794 g. of silver nitrate in distilled water and dilute to 1,000 cc. 1 cc. of this solution is equivalent to 10 mg. D.D.T. Check against standard potassium chloride.

(ii) *Petroleum Ether.*

The petroleum ether should have a boiling range below about 80°C. and must be free of sulphur compounds.

(iii) *The Adsorption Column.*

The apparatus found to be most satisfactory consists of a glass tube 3 cm. diameter (see alternative procedure for D.D.T.) and about 30 cm. long open at both ends. This is fixed by means of a rubber stopper into a 3G3 sintered glass filter, with the lower end of the tube resting on the plate. The tube is then packed with about 1 cm. absorbent cotton wool and the appropriate depth of alumina (Merck's standardized alumina is the best). A small layer of cotton wool is pressed on to the surface of the column to prevent any undue disturbance when in use. The efficiency of the column can be checked by watching the pigment bands. After washing with petroleum ether there should be a colourless band below the lower yellow band and no colour in the filtrate. If this is not so the column should be lengthened. The alumina may be recovered by washing with alcohol if necessary, drying and incinerating in a furnace at red heat for about two hours.

4. Errors Involved in the Method for D.D.T.

Providing chloride-free reagents are used, very little analytical error will be encountered. The most important source of error is that any compound of the general formula $R_1R_2CH—CClR_3R_4$ will interfere, but dichlordiphenyldichlorethylene (compound 2), of course, does not.

During the commercial synthesis of D.D.T., there is formed, in addition to D.D.T. itself, which is pp′-dichlordiphenyltrichlorethane, an isomer op′-dichlordiphenyltrichlorethane and this is not distinguished from D.D.T. by the present method of analysis. This source of error may, at times, be important since the relative proportions of the two isomers may vary in different samples of commercial D.D.T., and since the op′ isomer is much less toxic to insects than D.D.T.

Ten replicate analyses were run on 50 cc. samples of 0·5 per cent. D.D.T. and 0·03 per cent. pyrethrins made up in lighting kerosene. The mean result was 0·2508 g. D.D.T. and the standard deviation was 0·00078.

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Investigations into Production of Vegetables and Vegetable Seeds in the Red Cliffs District.

By J. E. Giles.*

Summary.

Investigations were conducted at Red Cliffs to determine the optimum sowing dates of root vegetables for use as root crops, and for seed production *in situ*. Experimental sowings were started in 1942, and were continued at monthly intervals from April 28, 1942, to March 26, 1943.

The vegetables were (*a*) Carrots (var. Chantenay), (*b*) parsnips (var. Hollow Crown), (*c*) red beet (var. Crimson Globe), (*d*) onions (var. White Spanish).

The main conclusions were as follows:—

(*a*) *Carrots (var. Chantenay)*.—All sowings from the end of August to the end of January were suitable for the production of a root crop and also for seed. Sowing at other periods, ultimately produced roots of marketable size. and some seed was also produced in each case.

(*b*) *Parsnips (var. Hollow Crown)*.—The February and March sowings failed to produce roots of a marketable size in a reasonably short time. The March sowing produced seed irregularly and in small quantities. All sowings, other than February and March, were considered good for both purposes.

(*c*) *Red Beet (var. Crimson Globe)*.—Sowings between late July and late November produced roots of marketable size in the shortest time. January to June sowings were the most satisfactory for seed production.

(*d*) *Onions (var. White Spanish)*.—Onions from seed sown during the summer months (November to March) failed to reach marketable size. Seed sown at any time of the year except March produced good seed crops, and those sown from April to October also yielded satisfactory root crops.

1. Introduction and Experimental Procedure.

War conditions have stimulated interest in the production of vegetables and vegetable seeds in the Murray Valley irrigation districts. The experiment described herein was commenced in 1942, to determine the optimal times of sowing seed of root crops to be used as vegetables, and for seed production. Details of the lay-out and treatment are shown below:—

Location.—Red Cliffs.

Soil type.—A deep sandy loam, common in the district.

Cultivation.—Soil ploughed, cultivated and worked to a fine tilth for seed sowing.

Manuring.—No fertilizers applied.

Vegetable crops included.—(*a*) Carrots (var. Chantenay), (*b*) parsnips (var. Hollow Crown), (*c*) red beet (var. Crimson Globe), (*d*) onions (var. White Spanish), (*e*) swedes (var. Purple Top)—(later discarded because of aphid damage).

Times of planting.—From April 28, 1942, to March 26, 1943, at monthly intervals.

Unit plot.—Four rows, each 32 feet in length, there being 2 ft. 3 in. between adjacent rows. Plants were later thinned to 18-24 in. apart in the row.

Treatment subsequent to planting.—Until the seed germinated and the young plants appeared above ground, spray irrigation was applied. Later the plots were irrigated by the furrow method.

* An officer of the Commonwealth Research Station, Merbein.

The plants were sprayed with nicotine sulphate or dusted with a nicotine dust when aphids became prevalent. Arsenical baits were laid when vegetable weevils attacked the young carrots in the spring months. The diameter of the roots near the crowns was measured at least once a month. From these measurements it was possible to determine the time taken for each vegetable to reach marketable size, and the rate of growth until seed was produced.

Carrots were regarded as having reached marketable size when the average root diameter was 3·2 cm. ($1\frac{1}{4}$ in.). Corresponding figures for the other vegetables were parsnips 4·5 cm. ($1\frac{3}{4}$ in.), red beet 7·6 cm. (3 in.), and onions 3·8 cm. ($1\frac{1}{2}$ in.).

In addition, the dates of seed production from each monthly planting were recorded, and samples of seed were kept for germination tests.

2. Growth and Seed Production.

(i) *Carrots.*

The number of days for the roots to reach marketable size decreased from 169 for the April sowing to 98 for the January sowing, and then increased to 120 days for the February sowing; the March sowing seeded without reaching marketable size.

The plants grown from seed sown during the months of April, May, June, and July, produced seed irregularly, plants running to seed from November until April. By September 13 most of the plants in these plots had developed root rot.

The number of days required for the roots to reach marketable size, the number of days to final seed collection, and the percentage of plants that produced seed are shown in Table 1 for each time of planting. The rate of increase in diameter of the roots is shown graphically in Fig. 1, for late spring to early summer, late summer to early autumn, late autumn to early winter, and late winter to early spring planting.

Table 1.—Growth and Seed Production Record of Carrots at Red Cliffs—1942-1943 Sowings.

Date of Sowing.	Reached Marketable Size.		To Seed Production.			Mean Diameter of Roots at Time of Seed Production.
	Date.	Number of Days.	Date.	Number of Days.	Percentage of Plants Seeding.	
						cm.
28.4.42	14.10.42	169	13.4.43	350	55	6·9
27.5.42	1.11.42	158	,,	321	49	5·7
24.6.42	26.11.42	155	,,	293	37	6.4
23.7.42	2.12.42	132	1.7.43	343	38	6·3
25.8.42	25.12.42	122	14.12.43	476	100	7·1
24.9.42	13.1.43	111	,,	446	100	6·5
28.10.42	12.2.43	107	,,	412	91	5·9
25.11.42	20.3.43	115	,,	384	100	6·5
24.12.42	31.3.43	97	,,	355	100	4·2
27.1.43	5.5.43	98	,,	321	100	6·0
24.2.43	28.6.43	124	,,	293	81	4·1
26.3.43	12.11.43	221	20.3.44	360	37	2·1

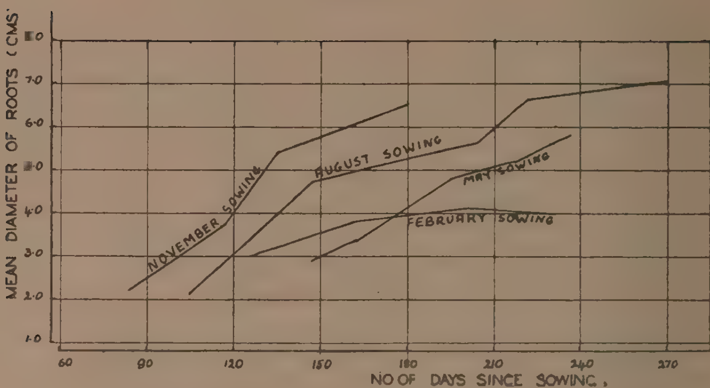

FIG. 1.—Growth studies of carrots sown at different times during the year.

(ii) *Parsnips.*

Parsnips from seed sown in April reached marketable size in 207 days. The time decreased until the August sowing, for which it was 139 days; and then remained fairly constant until the November sowing. From then on the time required increased to 176 days for the January sowing. The seed sown in February and March seeded before reaching marketable size.

Parsnips sown at all periods of the year except March seeded well. Only a few of those sown in March, 1943, produced seed by May, 1944; 4 per cent. seeded by December 14, 1943, and 14 per cent. by March 20, 1944.

The number of days in which the roots reached marketable size, the number of days to seed production, and the mean diameters of the roots at the time of seed production are shown in Table 2. The rates of increase in diameter of the roots are shown in Fig. 2.

TABLE 2.—GROWTH AND SEED PRODUCTION RECORDS OF PARSNIPS AT RED CLIFFS—1942-1943 SOWINGS.

Date of Sowing.	Reached Marketable Size.		Seed Production.			Mean Diameter of Roots at Time of Seed Production.	Viability of Seed.
	Date.	Number of Days.	Date.	Number of Days.	Percentage of Plants Seeding.		
						cm.	%
28.4.42	21.11.42	207	5.1.44	617	100	7·8	25
27.5.42	8.12.42	195	,,	588	100	7·9	43
24.6.42	30.12.42	189	,,	560	100	7·7	43
23.7.42	19.12.42	149	,,	531	100	7·8	51
25.8.42	11.1.43	139	,,	498	100	8·6	50
24.9.42	8.3.43	165	,,	468	100	6·6	54
28.10.42	28.3.43	151	,,	434	100	6·8	50
25.11.42	16.4.43	142	,,	406	100	5·8	44
24.12.42	This plot	was	accidentally	flooded	during	irrigation	
27.1.43	22·7·44	176	18.1.44	356	100	5·3	50
24.2.43	..	..	,,	328	100	3·5	40
26.3.43	..	..	25.5.44	426	14	..	69

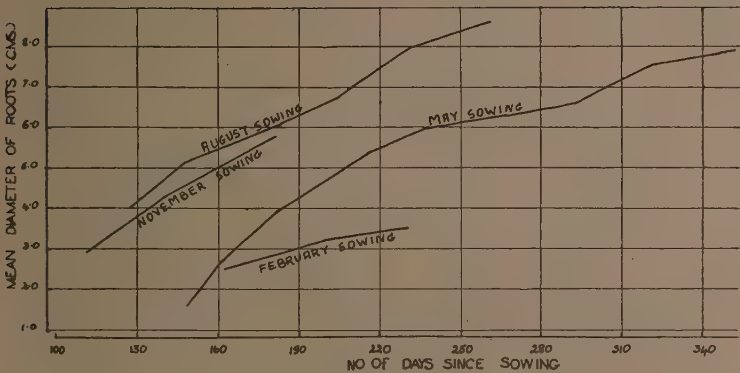

Fig. 2.—Growth studies of parsnips sown at different times during the year.

(iii) *Red Beet.*

Seed sown during the period July to November produced roots of marketable size in 100 to 118 days, which is shorter than the time required by seed sown during the remainder of the year. Seed sown in February or March failed to produce roots of marketable size.

The seed sown for each month during the April-October period produced roots of about 11 cm. in diameter at the time of production. With later plantings the size of roots at the time of seed production decreased until, for the March planting, the average diameter was 5·6 cm.

The percentages of plants that produced seeds are lowest for plants from the April, May, and June plantings. Nevertheless, those plants which did seed produced high yields of seed. The January, February, and March plots also produced good seed crops, but their yields were lower than from the April, May, or June plots. The seed heads that developed on the August to December plots failed in many cases to reach full maturity. There is a period of ten months between the dates on which seed was produced from the June and July plantings. Seed was harvested from the June, 1942, sowing on March 27, 1943, but not until January 25, 1944, from the July, 1942, sowing.

The number of days in which the roots reached marketable size, the number of days to seed production, and the mean diameter of the roots at seed production are shown, for each date of sowing, in Table 3. The rates of increase in root diameter are shown in Fig. 3 for four times of sowing.

TABLE 3.—GROWTH AND SEED PRODUCTION RECORDS OF RED BEET AT RED CLIFFS—1942-1943 SOWINGS.

Date of Sowing.	Reached Marketable Size.		To Seed Production.			Mean Diameter of Roots at Time of Seed Production.
	Date.	Number of Days.	Date.	Number of Days.	Percentage of Plants Seeding.	
						cm.
28.4.42	11.10.42	166	27.3.43	335	87	11·9
27.5.42	14.11.42	171	,,	306	90	9·5
24.6.42	12.11.42	141	,,	278	60	11·7
23.7.42	18.11.42	118	25.1.44	551	100	12·5
25.8.42	21.12.42	118	,,	518	100	10·4
24.9.42	11·1·43	109	,,	488	100	9·9
28.10.42	5.2.43	100	,,	454	100	10·3
23.11.42	19.3.43	114	,,	428	100	8·7
24.12.42	2.6.43	160	,,	397	100	7·4
27·1·43	19.7.43	173	,,	363	100	8·8
24.2.43	..	..	,,	335	100	6·2
26.3.43	..	..	,,	305	100	5·6

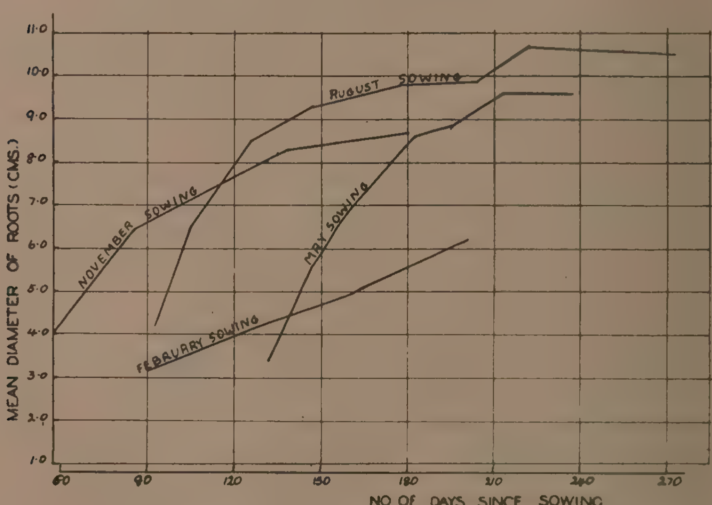

FIG. 3.—Growth studies of red beet sown at different times during the year.

(iv) *Onions.*

The time taken for the bulbs to reach marketable size decreased regularly from 223 days for the April sowing to 114 days for the September, and 125 days for the October sowing. The November to March plots failed to produce bulbs of a marketable size before they produced flower heads and seeded. The January plot was an exception, just reaching the diameter of one and a half inches in 229 days. With the exception of the March sowing, each plot produced seed uniformly.

There was a progressive decrease in the size of the bulbs from the April to March sowing. It was noted, in harvesting, that the yield of seed is roughly proportional to the size of the bulb.

There was no difference in the viability of the seed, as in all cases germination was greater than 95 per cent.

The number of days in which the roots reached marketable size, the number of days to seed production, and the mean diameter of the roots at the time of seed production are shown for each monthly sowing in Table 4, together with the viability of the seeds. The rates of increase in bulb diameter are shown in Fig. 4.

TABLE 4.—GROWTH AND SEED PRODUCTION RECORDS OF ONIONS AT RED CLIFFS—1942-1943 SOWINGS.

Date of Sowing.	Reached Marketable Size.		Seed Production.			Mean Diameter of Bulbs at Time of Seed Production.	Viability of Seed.
	Date.	Number of Days.	Date.	Number of Days.	Percentage of Plants Seeding.		
						cm.	%
28.4.42	7.12.42	223	18.1.44	630	100	8·2	96·4
27.5.42	12.12.42	199	,,	601	100	8·2	99·3
24.6.42	26.12.42	185	,,	573	100	7·3	99·5
23.7.42	19.12.42	152	,,	544	100	7·4	98·5
25.8.42	13.1.43	141	,,	511	100	5·7	96·6
24.9.42	16.1.43	114	,,	481	100	7·0	98·3
28.10.42	2.3.43	125	,,	447	100	5·6	95·5
23.11.42	..	..	,,	421	100	3·1	97·8
24.12.42	..	..	,,	390	100	1·7	97·8
27.1.43	13.9.43	229	,,	356	100	3·9	99·4
24.2.43	..	..	,,	328	100	2·4	100·0
26.3.43	..	..	,,	298	7	1·5	..

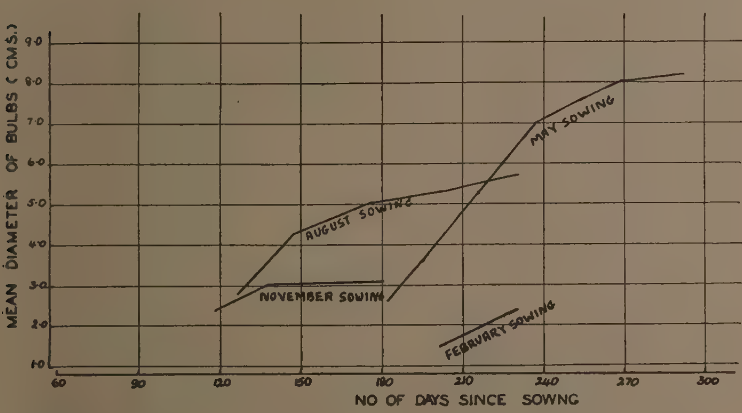

FIG. 4.—Growth studies of onions sown at different times during the year.

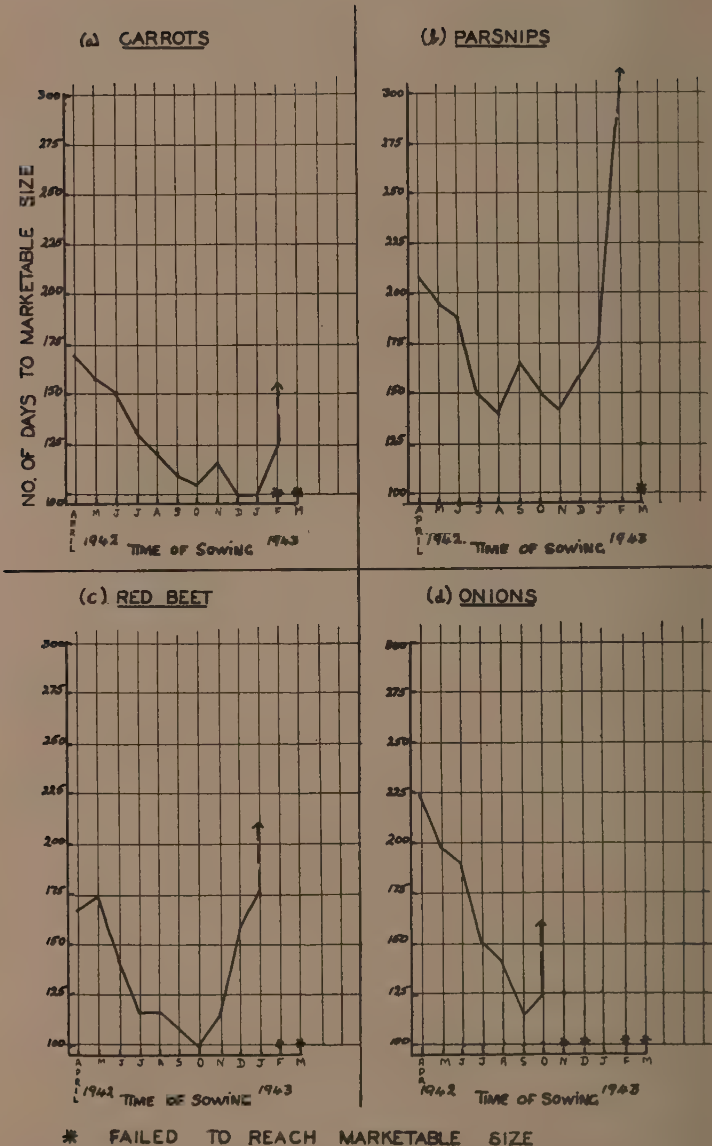

FIG. 5.—Number of days for vegetable roots to reach marketable size from seed sown at different times of the year.

3. Discussion.

The time required for the roots to reach marketable size varied, in general, with the time of the year at which the seed was sown. Carrots of marketable size were produced in 97 and 98 days from seed sown towards the end of December and towards the end of January respectively. The February sowing required 124 days, the March sowing failed to reach a marketable size, and the April and May sowings required 170 days.

The time required for parsnips to reach marketable size varied from 139 days for the August sowing and 142 days for the November sowing to 279 days for the February sowing, and the March sowing failed to reach marketable size.

Red beet seed sown in October produced marketable roots in 100 days. That sown in April, May, and January required about 170 days, and the February and March sowings did not reach marketable size.

Onion seed sown in the period November to March failed to produce, or barely produced, bulbs of marketable size. The August sowing produced bulbs of marketable size in 139 days. The April sowing required 207 days.

The times required for the roots to reach marketable size from seed sown towards the end of each month of the year are shown graphically in Fig. 5.

Carrots grown from seed sown from March to July flowered irregularly, between one-third and one-half of the plants producing seed at some time during the following summer. Those from seed sown during the period August-January produced seed uniformly during the month of December, i.e., 11-16 months after sowing. The February sowing was intermediate, 81 per cent. of the plants producing seed in the following December.

Seed production from parsnips and onions occurred during January, 11 to 21 months after sowing for all sowings except March, from which seed production was irregular, less than one-fifth of the parsnips and only 7 per cent. of the onions producing seeds during the next fourteen months.

The larger proportion of red beet plants from seeds sown during April to June, 1942, produced seed during the following March; i.e., in a period of 9 to 11 months. Those from the July to March sowings did not produce seed until January, 1944, i.e., a period of 10 to 18 months.

Although no records were kept of the amounts of seed produced, it was observed that the amount was roughly proportional to the size of the roots. In general, the older the plants at the time of seed production, the larger were their roots, and the greater their yield of seed.

It is recognized that seasonal conditions and soil type markedly affect vegetable production in this district. On account of this, the results described above may exhibit some variation under different seasonal and soil environment. In particular, crop establishment is difficult on light sandy soils during hot windy weather which is often experienced during the summer months, and many growers refrain from sowing seed during this period.

4. Acknowledgments.

The co-operation of the Mildura Shire Council and the State Rivers and Water Supply Commission is gratefully acknowledged for making available the land and the water respectively.

For assistance in the field work and the records the writer desires to thank Mr. D. V. Walters, Miss R. Hill, and Mr. W. J. Webster of the staff of the Commonwealth Research Station, Merbein; also Mr. E. M. Hutton and Mr. D. C. Wark, of the Division of Plant Industry, Canberra, for help in this report.

Flax Processing: The Need for Research.

*By W. L. Greenhill, M.E.**

1. Introduction.

Prior to 1936 linseed flax had been grown in selected areas in Australia for at least 40 years, but on the whole, with little financial success. This was perhaps to be expected, as there were very limited manufacturing requirements in Australia and practically no export demand, and the production interests were handicapped by limited capital, lack of experience in modern production methods, and general inefficiency. In 1936, however, a company known as Flax Fibres Pty. Ltd., was formed by two Victorian spinners who set out to make use of modern equipment and up-to-date methods of production. They commenced by introducing flax seed of a high-grade fibre-producing variety and, starting with 200 acres in 1936, the area under cultivation had been expanded tenfold by 1939.

Soon after the outbreak of war, the curtailment of the normal supplies of flax to Great Britain emphasized the potential value of the Australian industry to the war effort and all flax production in this country was taken under the control of the Commonwealth Government. A greatly increased production programme was immediately commenced; approximately 21,000 acres were sown in 1940 and about three times this area each year since. To carry out this programme has required the establishment of over 30 flax mills distributed amongst four States, and the capitalization of the industry to the extent of about £1,000,000.

2. Past Research at the Division of Forest Products.

The need for scientific research in the establishing of a successful industry was realized by Flax Fibres Pty. Ltd., when they commenced operations in 1936. The latest overseas information was obtained and in 1937 a grant was made by the company to the Council to assist in the establishment of a Flax Research Section. This Section was

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attached to the Division of Forest Products and concerned itself with processing problems—particularly water retting. Only a small staff and little equipment were available at this time, but the foundations of a satisfactory water-retting technique for Australian conditions were established and a good deal of experimental work was carried out at Colac where the only commercial water-retting plant in Australia was in operation.

The expansion of the flax industry after the outbreak of war brought with it many problems in both growing and processing. It became the function of the Flax Section of the Division of Forest Products to assist the Flax Production Committee in the establishment of sound processing methods. To this end the staff of the Section has been increased considerably and a thorough study is being made of those aspects of fibre processing most likely to yield substantial improvements in the flax industry. The work already completed is outlined below under the headings of the main processes involved in fibre production:—

(*i*) *Harvesting.*

So far this has not been considered as one of the problems of the Division, but the question of reaping versus pulling has been examined carefully from the angle of fibre recovery and recommendations regarding the most economical practice have been made.

(*ii*) *Deseeding.*

Investigations have been made to determine the damage to straw during deseeding by the old method of rollers and by the use of the Soenen's type of machine. Recommendations for reducing damage have been made.

(*iii*) *Retting.*

(*a*) *Water Retting.*—The accepted methods of water retting flax are based on a mass of empirical knowledge. The problem as it affects this country has been to adapt overseas methods to local conditions and if possible improve on them by making retting a science rather than an art. A comprehensive study has therefore been made of the physical factors involved. This work has been carried out on both a laboratory and commercial scale and has gone far to simplify and standardize the Belgian practice. The influence of the following factors on the rate of retting and the yield and quality of the fibre has been studied:—

(1) The effect of infiltrations of varying amounts, frequency, and temperature.

(2) The use or otherwise of a preliminary rinse and the effect of its duration and temperature. This work has been extended to include the so-called "interrupted" ret.

(3) The effect of different temperatures at various stages of the ret.

(4) The effect of various ratios of water to straw.

(5) The use of a final wash.

(6) The effect of various weeds.

(7) The effect of using brackish water of various degrees of salinity.

(8) The effect of leaving seed on the straw during retting.

In addition, methods for determining the end-point of a ret have received much attention; the uniformity of retting in commercial tanks of different dimensions has been studied and assistance has been given in the design of commercial plants. Water from some fifteen different localities has been analysed to test its suitability for water retting and steam raising. A study has been made of the nature of the effluent from water retting and methods of treating it suggested; recently assistance has been given in the commercial application of the recommended treating procedure.

Certain special types of ret such as the double ret, channel or continuous retting, and the "Duplex" ret have been the subject of experiments and the particular advantages and disadvantages of these techniques ascertained. Preliminary tests have been made of various chemicals to accelerate water retting and possibly improve the quality of the fibre.

(*b*) *Dew Retting.*—No systematic investigation has been made of dew retting but some exploratory work has been carried out on the following aspects of the process:—

(1) The effect of time of year on retting period and fibre quality.

(2) The effect of thickness of straw.

(3) The possibility of dew retting in racks under artificial moisture control.

(*c*) *Chemical Retting.*—A successful process for chemically retting flax has been developed after several years' research, and has advanced to the pilot plant stage. The complete treatment occupies about eight hours as compared with approximately 96 hours for water retting, and the fibre from the chemically retted straw gives every promise of spinning at least as well as water retted fibre from matched straw. The final verdict on the process as a commercial proposition now awaits the results of overseas spinning tests.

(*iv*) *Drying.*

Experiments have been made on a laboratory scale of the artificial drying of water-retted flax straw. From the results of these tests a commercial dryer was designed and units subsequently erected at two flax mills. Thorough tests of the performance of these units have been made. Difficulty was experienced in obtaining uniform drying, a trouble common to all flax dryers and one which follows from the uneven nature of flax straw, the difficulty of spreading wet straw uniformly, and the matting effect of various weeds.

Pressing rollers for squeezing out part of the moisture prior to drying were also tried at some length and, although greatly improving the output of a dryer, introduced further handling costs and left artificial drying still unable to compete successfully with natural drying.

(*v*) *Scutching.*

Studies have been made to determine the optimum moisture content of straw for scutching and various methods of attaining this condition

have been tried. Experiments have been made with the standard scutching machine to determine the most satisfactory clearances of the beater blades and of the effect of various modifications to the blades. Different types of fluting on the breaker rollers and various numbers of breaker rollers have also been tried.

In order to study the action of the blades of a turbine scutcher in greater detail than is possible on a commercial machine, a model has been constructed on which movements can be examined stroboscopically. Modifications have been recommended which it is considered will reduce the amount of tow and eliminate damage to the ends of the fibre.

Certain suggested methods of cleaning tow have been examined and reported on.

(*vi*) *Chemical Investigations.*

It has been considered that for a fundamental understanding of the processing of straw, a knowledge of the chemistry of the straw before and after retting and of the fibre is essential. The value of such information in assessing retting methods and in evaluating fibre has been evidenced from time to time. For this reason a considerable amount of work has been carried out developing methods of analysis for the main types of constituent bodies. The work has been difficult because of the complexity of the materials present, but is now well advanced and has been extended from the main products of the industry to cover the chemistry of linseed and shives.

(*vii*) *Physical Investigations.*

One of the main difficulties in research work on flax, both from the agricultural and processing aspects, is the evaluation of the fibre. The agricultural experimentalist would welcome a simple means of determining the yield and quality of the fibre from an examination of the green straw; after processing, the fibre may be examined by graders but the personal element associated with the judgments of even experts in this field, gives variable results often difficult to reconcile. Actual spinning tests are restricted to a few cases where a comparatively large quantity of fibre is available and even then the absence of any laboratory spinning plant makes tests, which are carried out at commercial factories, often of doubtful value.

In an effort to establish means for evaluating fibre, both in the straw and after processing, a considerable amount of work has been carried out to correlate various physical properties with fibre quality. For the straw, investigations have been concerned mainly with microscopic characteristics. The size, shape, and distribution of the fibre bundles can often be used to assess the general quality of the product. To enable microscopic sections of the straw to be made rapidly and simply a freezing technique has been developed which is most successful.

Examination of the processed fibre itself has been made by microscopic examination, tensile and impact tests, hackling yield, and weight distribution. The use of fibre fineness and hackling yield as an index of fibre quality appears most encouraging and has been made quite practical by the development of a rapid and simple method of measuring fibre fineness by air permeability.

For investigating the various physical properties, it has often been necessary to develop special equipment and to establish a suitable testing technique before actually attempting to use the property as a possible guide to fibre quality.

(viii) Co-operation with Agricultural Research.

To assist agricultural workers in selecting the most suitable flax varieties, fertilizers, and methods of cultivation, some hundreds of samples from field trials have been carefully prepared and processed. A large amount of work is entailed and results are not spectacular but will, it is hoped, assist in the establishment over a period of years, of improved flax types and methods of cultivation specially suited to Australian conditions.

(ix) Miscellaneous Investigations.

Many minor investigations have been made as the result of enquiries from various sources. These include such widely divergent fields as the selection of suitable protective paints for retting tanks, the effect of wilt and rust on fibre yield and quality, a comparison of flax tow with other packaging materials for inflammability and cushioning, and the feasibility of decapitating the seed heads of straw to facilitate subsequent handling.

In addition, some eighteen miscellaneous fibrous plants have been received for examination as to their commercial value. In all cases, methods of extracting the fibre have been experimented with and the value of the final product assessed. In some instances a market has been found for the products but difficulty in arranging supplies is usually encountered.

3. Future Research.

The time has now come when a big step forward must be taken in flax research if the results already obtained are to be consolidated and the future of the industry in this country is to be safeguarded. Recent research has been mostly of an applied nature but fundamental investigations in addition are most desirable as the surest method of advancing the ultimate efficiency of the industry.

That there is ample opportunity for research is evidenced by the fact that at present only about 50 per cent. of the fibre in the straw is recovered in the form of long fibre. The balance is lost or recovered only in the form of tow, which is of much less value. If the line fibre obtained from the straw were increased by only 1 per cent.—a very moderate figure—the saving to the industry would be many thousands of pounds per annum.

Some specific indications are given below of the lines of flax processing research considered to be most promising for the immediate future.

(i) Harvesting.

Although the present methods of harvesting adopted in this country, including dual harvesting, would appear satisfactory, it would be entirely

wrong to assume that no improvements could be made. For instance, some modification to harvesting methods or equipment which would give a shorter stubble and correspondingly longer straw would be of great value, especially during dry years when crops are short and often on the borderline as to whether or not they are worth cutting.

(*ii*) *Deseeding and Winnowing.*

Various types of deseeding machines are in use and the relative efficiency of these requires critical examination, especially the extent to which each type damages the straw. A prerequisite is a study of the effect of deseeder damage to straw on retting and on the yield of line fibre.

Mechanical modifications designed to improve the efficiency of the Soenen's Deseeder should be tried out.

Mill winnowers are required to clean flax seed to a standard of 95 per cent. whole seed. For this purpose they are admittedly inefficient and require further study and improvement.

(*iii*) *Retting.*

There seems little doubt that the production of flax in this country will continue to be based on retted rather than green fibre. Considerable criticism has been levelled at Australian fibre both here and overseas because of its generally harsh nature and poor spinning quality which is attributed largely to adhering cortical tissue. This tissue is not removed by conventional retting procedures and the development of a retting technique which will produce fibre of high spinning quality will go far to ensure the success of the flax industry in Australia.

(*a*) *Water Retting.*—A large part of the success of the well-known Belgian method of retting has been due to factors prior to the retting itself, the selection of the crops in the field, the sorting of the straw, and an extreme care in handling at every stage. Such factors must not be overlooked in retting research programmes.

While further experiments should be made with modifications of the Belgian method of retting, such as double, interrupted, and aerated retting, and be extended to a more comprehensive range of straw types than so far examined, there is no indication of any outstanding development along these lines.

The addition of certain chemicals to the retting liquor is a more promising field of investigation which so far has only been touched. Suitable chemicals would produce accelerated retting and improve fibre quality. In these and all the water retting investigations it is very desirable that a biological study be made of the characteristics and development of the bacteria responsible for the process.

(*b*) *Dew Retting.*—Although more than half the straw retted in this country is by dew retting, investigations of even the more practical aspects of this procedure have been virtually neglected. Admittedly such studies are made more difficult because they are largely regional and because they must be repeated over a number of years to eliminate climatic vagaries. Nevertheless, in view of the expansion of dual

harvesting and the probability that dew retting will continue to be of importance in this country, work on this process should be included in any future research programme. Attention should be given to the effect on the rate of retting, the development of the biological organisms involved and on the yield and quality of fibre of such factors as:—

Time of year in which the straw is spread.

Thickness of spreading in relation to time of spreading.

Maturity, diameter, and general condition of straw.

Variety of flax.

Substratum on which straw is spread.

(c) *Chemical Retting*.—The future of chemical retting is somewhat problematical at the present time as the results of overseas spinning tests are not yet to hand. The process may offer a means of producing a fibre in this country with high spinning quality and should not be abandoned until such possibilities are thoroughly explored.

(*iv*) *Drying*.

The problem of drying water-retted straw by natural means is not so difficult in Australia as, for example, in England, and it does not appear that further large scale experiments on artificial drying would be justified, particularly as these would largely duplicate work already being done in England. It is suggested, however, that the use of a small dryer for finishing off partially dried straw during adverse weather would be a most valuable adjunct to any mill.

Associated with drying is the question of raising the moisture content of straw during hot dry weather to a value suitable for scutching. This is an urgent problem which is already being attacked both here and overseas. The success of present investigations will determine the need or otherwise of further work.

A prerequisite to work on conditioning straw for scutching is the determination of the optimum moisture content of the straw. The work already carried out on this problem has been of a preliminary nature only and should be extended to a comprehensive examination of a full range of straw types both water retted and dew retted. Such investigations should include the evaluation of equilibrium moisture contents for straw and other flax products and the fundamental study of the mechanism of the method of association of moisture and of the mechanism of moistening flax straw.

(*v*) *Scutching*.

Mechanical improvements in the scutching of straw to permit a higher recovery of line fibre together with a higher rate of output, offer scope for almost unlimited research of a most profitable nature. Since the type of scutching machine now in use at the mills was first designed, a good many minor improvements have been made, but no major research has yet been undertaken. Their performance with well handled high quality straw is reasonably good but there is definite room for improvement so that they may deal with the lower grade straws to

better advantage. This may mean further improvements to the existing type of machine or, on the other hand, a completely new form of scutcher which will give a line fibre to tow ratio closer to the theoretical maximum.

Until a scutcher is devised which will deal to best advantage with each type of flax presented to it, the problem should be approached from the angle of always presenting the straw to the existing machine in the most suitable form. If a machine could be devised to take a bundle of flax straw, spread it in a thin even layer with the straws perfectly parallel and butt ends perfectly aligned, and then feed the layer uniformly to the scutcher, the fibre yield might easily be improved by 25 per cent. and the output by an even greater amount.

The development of an economical and efficient tow cleaning machine has been, and is, receiving considerable attention. From a survey of the stage of development already reached, it would be possible to decide on the need or otherwise for still further work in this field. The best solution to the problem is, undoubtedly, the reduction of tow to a much lower percentage than at present.

(*vi*) *Mill Studies.*

An investigation of the manual and mechanical handling of straw and fibre at mills is suggested for the purpose of devising improvements in technique and eliminating any superfluous procedures. Time studies of various operations may indicate opportunities for preventing bottle-necks in production.

(*vii*) *Utilization of By-Products.*

It is by no means certain that the fields of utilization for flax by-products have been exhausted. Some of the present uses have been made possible because of a war-time shortage of other materials so that new uses may have to be developed. No avenues should be left unexplored and, in particular, research as to the possibility of using flax shives with other agricultural residues in plastic compositions should be encouraged.

(*viii*) *Fibre and Straw Evaluation.*

Scientific studies of the straw and fibre, both chemical and physical, are necessary to provide a complete evaluation of their properties and potentialities. They also provide a background of information for improvements in processing technique and in the utilization of the fibre and flax by-products.

(*a*) *Physical Investigations.*—Methods of determining the more important strength properties of flax fibre have already been developed, but other factors such as elastic and plastic deformation under stress and flexural endurance are also highly important. Facilities for the microscopic study of straw and fibre need to be greatly extended and should include the use of polarized and ultra-violet light. The measurement of fibre dimensions is likely to provide a useful guide to fibre behaviour.

A knowledge of the chain of physical phenomena relating fibre properties to product properties would provide a much more efficient basis on which to predict product behaviour. With the large number of interacting fibre properties involved, the theoretical approach has remained in a rather undeveloped state but a physical theory of yarn properties is envisaged as a distinct possibility.

(*b*) *Spinning Tests.*—The desirability of obtaining a pilot spinning plant for use in fibre evaluation cannot be over-emphasized. Despite the difficulties involved, the matter should be pursued until suitable equipment is forthcoming.

(*c*) *Chemical Tests.*—The fundamental study of the chemical constitution and properties of straw, fibre, and by-products should be continued.

(*d*) *Co-operation in Agricultural Field Trials.*—Assistance to agricultural workers in retting and evaluating the fibre from their field trials must continue to be provided.

As time goes on and fewer variables are under consideration, these field trials will be made on a much larger scale; it will then be possible to extend the evaluation tests to include spinning.

(*ix*) *Spinning and Weaving.*

While the problems which are of immediate concern are those of raw material, it will be necessary, if linen is to compete with synthetic and other fibres, to determine whether anything can be done to improve still further the appearance and handling of linen fabric without sacrificing any of those qualities for which it is already famous. One avenue of possible research would be the use of synthetic resin impregnations which, in other fabrics, give such desirable properties as waterproofing and crease-resistance. Much may be possible to facilitate present methods of spinning, weaving, and finishing.

4. Finance for Research.

It is not the intention of the present article to discuss this question in any detail, but a few pertinent figures may be of interest. Assuming an immediate post-war flax industry of 30,000 acres with a net return of 5,000 tons of fibre valued at £100 per ton, it would not appear to be out of proportion to spend £10,000 per annum for maintaining an organization for processing research. In addition to this, the extent to which spinners and weavers would benefit from such an establishment should be taken into consideration. The eventual extension of the research facilities so provided to include flax spinning and weaving investigations must be envisaged as a definite possibility.

The Relation of *Polyspora lini* Lafferty and *Pullularia pullulans* (de Bary) Berkh. to Flax Browning.

*By N. H. White, M.Sc.**

Summary.

1. From flax affected by browning disease in Tasmania, fungi associated with dew-retting of flax were isolated, namely, *Pullularia pullulans*, *Alternaria*, and *Cladosporium*.

2. Cultures of *Pullularia pullulans* were compared with cultures of *Polyspora lini* isolated from browning-diseased flax from Victoria, New Zealand, and Ireland. Cultures bearing both names could not be satisfactorily distinguished on the basis of microscopic structure, cultural, serological and physiological characters, capacity to ret flax, or pathogenicity reaction on flax.

3. It is suggested that *Pullularia pullulans* and *Polyspora lini* should be considered as belonging to the same genus *Pullularia* and that the latter might be referred to as *Pullularia pullulans* var. *lini*. The fungus is weakly parasitic and non-pathogenic. Comb. nov

4. The relation of these fungi to the development of browning symptoms in flax and seed disinfection is discussed.

1. Introduction.

A disease of flax (*Linum usitatissimum*) known as "browning" and "stem-break" was described by Lafferty (1921) in Ireland. Since then the disease has been reported in most flax-growing countries, and the literature has been reviewed by Baylis (1941). In some reports both browning and stem-break symptoms were associated, but in others only browning symptoms were recorded. In Tasmania during the 1942 and 1943 seasons respectively, browning symptoms were observed in some flax crops by H. R. Angell and the writer, but there was no evidence of stem-break. There appears to be some doubt about the constant association of browning and stem-break. Only the browning phase is being investigated by the writer.

Lafferty erected a new genus and species, *Polyspora lini*, for the fungus he claimed as the cause of both browning and stem-break. Since then the identity of this fungus and the validity of the claim that it is a pathogen have apparently remained unquestioned. From Tasmanian-grown flax showing browning symptoms the writer isolated *Pullularia pullulans* (de Bary) Berkh., which resembled very closely isolates of *Polyspora lini* from other parts of the world. An attempt was made to distinguish between cultures bearing the two names, and the results of this study are reported here.

2. Browning Disease in Tasmania.

In the 1942-43 season Concurrent flax in some parts of Tasmania, just before harvest time, showed symptoms typical of those described by Lafferty for browning disease. Stems of diseased plants were examined in the laboratory both by the moist chamber method and by

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plating surface-sterilized tissue on malt-extract agar. Platings were made from three portions of the stem: (i) the stem base (0-1 inch); (ii) parts without lesions, and (iii) parts with lesions. In all, 63 plants were plated in this way. Five fungi were dominant in these platings, namely, *Pullularia, Fusarium, Cladosporium, Alternaria*, and *Phoma*. The percentage of pieces of plant tissues yielding these fungi are shown in Table 1.

TABLE 1.—PERCENTAGES OF PLANTS YIELDING DIFFERENT FUNGI FROM PLATINGS ON MALT EXTRACT AGAR.

Part of Plant Plated.	Percentage of Plants Yielding—				
	Pullularia.	*Fusarium.*	*Cladosporium.*	*Alternaria.*	*Phoma.*
Stem base 0–1 in. ..	0	80	20	55	10
Non-lesioned stem ..	5	2	9	8	5
Lesioned stem ..	69	14	50	71	45

It will be seen that lesioned tissue gave high yields of all the fungi. The basal portions of the stem yielded no *Pullularia*, but more *Fusarium* was found there than elsewhere. Amongst the isolates of *Pullularia*, variations occurred in thallus characters but not in microscopic characteristics. The same variations were also observed by the writer amongst isolates of *Pullularia* from dew-retted flax.

Flax seed of different origin, including browning diseased crops, was tested for germination and for seed-borne organisms by the Ulster method (Muskett and Malone, 1941). The results of this examination are shown in Table 2.

TABLE 2.—FLAX SEED EXAMINED BY ULSTER METHOD.

Origin of Seed.	Condition of Crop.	Germination in Soil.	Germination by Ulster Method.	Organisms Obtained by Ulster Method of Testing.				
				Fusarium.	*Alternaria.*	*Cladosporium.*	*Pullularia.*	Bacteria.
		%	%					
Bowman, Deloraine	Browning	72	27	69	1	6	40	90
Cameron, Deloraine	No symptoms	74	10	25	1	10	41	100
Cameron, Deloraine	Browning	67	17	44	2	15	51	99
Cox, Branxholm ..	No symptoms	86	12	20	10	32	56	97
Deloraine seed growers—seed treated with Ceresan	.. ..	79	94	0	0	0	0	0

Germination in pots of soil was practically the same, whatever the source of the seed. The low germination of seed plated on malt extract was apparently due to the presence of saprophytes which are inimical to germination. This was borne out by the high germination of seed treated with Ceresan. The inhibiting effect on germination by fungi including *Pullularia,* has been frequently observed. It will be seen from Table 2 that except for the seed treated with Ceresan, there were only small differences in the organisms occurring on seeds from different sources, and that in all samples the *Pullularia* isolations were about the same.

The writer was unable to find any evidence of acervuli or other structures similar to those described by Lafferty on any of the tissues or seeds examined. The only fungus found on the diseased flax that resembled *Polyspora lini* was *Pullularia pullulans*, the essential features of resemblance being the production of slimy radula spores, with a yeast-like budding process. Cultures of *Polyspora lini* were obtained from Victoria, New Zealand, and Ireland. The striking resemblance of these cultures to those of *Pullularia pullulans* was noted immediately. It seemed that the fungus isolated from the Tasmanian flax might be *Polyspora lini.* It was, therefore, decided to attempt to distinguish *Polyspora lini* from *Pullularia pullulans.* In order to do this a comparative study was made of the morphology, physiology, serology, ability to ret flax, and pathogenicity on flax of isolates of both fungi.

Before presenting the results of this comparative study the taxonomy and pathogenicity of both fungi will be reviewed.

3. *Polyspora lini* Lafferty.

Lafferty isolated this fungus by plating conidia that were produced on diseased flax stems. The fungus developed its mycelium slowly on artificial media, but conidia were always produced in great abundance. " The surface of the medium became covered with a cream coloured mass of conidia resembling bacterial growth." The conidia have " bluntly pointed ends, are hyaline, single-celled and of varying shape, oval, cylindrical and straight forms with a peculiar basal twist . . . . . Though very uniform in breadth which averages 4μ they vary greatly in length, the extremes being 9μ and 20μ with an average of 15μ ". Many of these conidia produced new conidia from the ends. These conidia are figured in Lafferty's paper, and he places the fungus in the *Melanconiales* on the grounds that the conidia are produced in acervuli.

Lafferty claims proof of the pathogenicity of *Polyspora lini* on flax. He sprayed well-grown flax in pots after petal fall with a suspension of conidia in sterile water. After inoculation the plants were covered with a bell jar, the first symptoms showing 20 days later. These were elongated brown areas on the stems. On removing and examining the diseased tissue " typical acervuli, made up of the conidia and conidiophores of the fungus," were found. Lafferty also sprayed an area of 4 square yards of flax in the field, and " after a lapse of sixteen days the plants in the plot sprayed with the conidial suspension had become distinctly brown, and resembled in every detail those naturally affected with the disease ".

Subsequently, the pathogenicity of *Polyspora lini* has been accepted. Some have repeated the work and have claimed positive results. In 1941 Baylis in New Zealand reported that he tested isolates of a fungus identified as *Polyspora lini* on a number of varieties of flax and found that some varieties showed some resistance to infection. The tests were made by spraying conidial suspensions on to flax before and at the flowering stage. After spraying, the plants were kept in moist chambers for four days. Typical symptoms of browning followed, and from this tissue the fungus was re-isolated.

4. *Pullularia pullulans* (de Bary) Berkh.

Many synonyms are found in the literature for this fungus. Saccardo lists the following: *Cladosporium herbarum* (Pers) Link, *Acladium herbarum* Pers, and *Dematium pullulans* de Bary et Lowe. Other synonyms are *Aureobasidium* Viala and Boyer, *Hormonema dematioides*, and *Hormonema pullulans*. For a long time the generic name *Dematium* de Bary was used, but it has now been amended to *Pullularia* Berkh. (Wakefield and Bisby, 1941.)

In 1866 de Bary described *Dematium pullulans* as " a fungus consisting of a septate mycelium from the segments of which ellipsoidal cells sprout freely at the ends or the sides. After exhausting the available food supplies the hyphae divide transversely into cells which are isodiametric; these swell up into roundish-shaped segments with two layered walls and contents rich in oil, meanwhile assuming a brownish black colour ".

Bennett (1928) demonstrated the natural occurrence of the ascigerous stage of *Dematium pullulans* on wheat straw. He described and named the fungus *Anthostomella pullulans* (de B.) Comb. nov., the genus belonging to the *Sphaeriales*. Cultures derived from ascospores of this fungus resembled cultures of *Dematium pullulans* isolated from various sources by Bennett. These are illustrated in his paper, together with the slope cultures of various strains of the fungus.

Pullularia pullulans shows variations in cultural characters, but no clear microscopical differences. This has undoubtedly contributed largely to the wide synonomy and confusion surrounding this fungus. Bennett recognized at least six strains of *P. pullulans* from various sources including one from an ascospore of *Anthostomella*. They all produced a conidial stage indistinguishable microscopically from each other. They differed, however, in cultural characters on different media. In colour they varied from pale-buff to olive-black, depending on the development of chlamydospores.

P. pullulans was isolated from many sources by the writer, and the following are recorded in the literature: On calico and textiles, producing dark stains; in food containers and on butter and meat; in orchard soils; in pharmaceutical preparations; on wheat roots; in the seed coats of ryegrass and peas; in lesions on cherries affected by brown rot in storage; associated with pear decay; in lesions of needle blight of conifers; in blue staining in timber and wood pulp, and associated with forking of red pine in U.S.A.; with blind seed disease of ryegrass in different parts of the world; with autumn browning and needle blight of pines in

California; and with low germination of pea seed—but in no instance has *P. pullulans* been shown to be pathogenic. It was isolated from seeds of 48 species of trees and 28 species of conifers in the U.S.S.R.

In 1941, Jensen reported *P. pullulans* as a flax-retting agent for the first time. It was isolated from dew-retted flax along with *Cladosporium* and *Alternaria*. Isolations made by the writer from dew-retted flax from many sources revealed that *P. pullulans* was always present, and experimental retting of flax by pure cultures of different fungi established that *P. pullulans* was a good fungal retting agent. The writer has isolated this fungus from flax straw at all stages of development and has found it almost universally present on grasses and cereals.

5. Comparison of Isolates of *Polyspora lini* Laff. with Isolates of *Pullularia pullulans* (de Bary) Berkh.

For the comparative studies of these fungi, two isolates of *Pullularia pullulans,* and four isolates of *Polyspora lini* were used. The source of each isolate is shown in Table 3 together with cultural characters and spore sizes. Morphological comparisons were made on potato-dextrose agar and potato slope media. The culture colours and characters developed on these media were noted. The size of sprout cells and abundance of mycelium was observed on three-day old cultures grown on potato-dextrose agar at 25°C.

TABLE 3.

Culture Number	P1.	P2.	P5.	P6.	P8.	P9.
Origin of culture	Canberra	Tasmania	Koo-wee-rup, Victoria	Myrtleford, Victoria	New Zealand	Dr. Muskett, Ireland
Organisms ..	*Pullularia*	*Pullularia*	*Polyspora*	*Polyspora*	*Polyspora*	*Polyspora*
Culture characters on P.D.A. slopes 12 days at 25° C.	Black, moist, granular	Black, moist, smooth	Black, moist, smooth	Black, moist, smooth	Black, moist, smooth	Pink to black, moist, granular
Culture characters on potato slopes— (i) 11 days	Dirty buff, black centre	Dirty buff	Dirty buff	Dirty buff	Waxy pink	Waxy pink
(ii) 24 days	Black, dry, carbonaceous	Buff, moist, smooth	Black, wrinkled, moist	Black, moist, wrinkled	Greenish black, moist	Black, moist, wrinkled
Chlamydospores on P.D.A. in 7 days	Present	Absent	Present	Present	Absent	Absent
Sprout-cells on P.D.A.— Shape ..	Oblong-lenticular	Oblong-lenticular	Oblong-lenticular	Oblong-lenticular	Oblong ..	Oblong
Mean size ..	$6 \cdot 5\ \mu \times 4 \cdot 0\ \mu$	$6 \cdot 6\ \mu \times 3 \cdot 1\ \mu$	$6 \cdot 8\ \mu \times 3 \cdot 6\ \mu$	$6 \cdot 6\ \mu \times 3 \cdot 6\ \mu$	$9 \cdot 2\ \mu \times 2 \cdot 5\ \mu$	$12 \cdot 3\ \mu \times 3 \cdot 7\ \mu$

Physiological comparisons were made by testing their ability to grow and produce acid and gas on liquid media containing different carbon sources, following the same technique as adopted in the identification of bacteria. The results are shown in Table 4.

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Serological studies were made according to the technique of Reid *et. al.* (1942). Rabbits were used for making the antigen. Sensitization was carried out at 30°C. for a period of 18 hours, and the degree of microscopic agglutination recorded. The results are shown in Table 4.

TABLE 4.—PHYSIOLOGICAL AND SEROLOGICAL REACTIONS OF *Pullularia* AND *Polyspora*.

Culture.		P1.	P2.	P5.	P6.	P8.	P9.
Physiological Reactions	Methyl red	..	..	..	..	..	..
	Glucose ..	+++ A	+++ A	+++ A	+++ A	+++ A	+++ A
+ = growth	d-Xylose	+++ A	++ A	++ A	+	++ A	+++ A
A = acid	Maltose ..	+++ A	+++ A	++ A	+++ A	++ A	+++ A
	Levulose	+++ A	+++ A	+++ A	+++ A	+++ A	+++ A
	Lactose ..	++ A	++ A	++ A	++ A	+ A	++ A
	Galactose	+	+	+	+	+	+
	Saccharose	+++ A	+++ A	+++ A	+++ A	+++ A	+++ A
	Citric acid	+++	+++	+++	++	+	++
	Succinic acid	+++	+++	+++	+++	+++	++
	Tartaric acid	+	+++	++	+	+	+
	Mannitol	++	++	++	+	+	+
	Glycerol	++	+++	++	+++	++	++
	Salicin ..	+++	++	+	+	+	+
Serological Reactions	Antigen—						
+ = amount of agglutination at dilution 1 in 450	P1 ..	+++	++	++	+++	++	+
	P2 ..	++	++	+	+	+	++
	P5 ..	++	+++	+++	++	++	++
	P6 ..	++	+	+++	+++	++	+++
	P8 ..	++	++	++	++	++	++
	P9 ..	++	+	++	+++	++	+++

The retting property of each isolate was determined by inoculating sterilized flax straw contained in 24-inch test tubes and noting the time for the complete retting of the flax.

It will be observed from Table 3 that variations occur in all six isolates for culture characters on different media, chlamydospore development, and sprout-cell size and shape. These variations are as great within isolates of *Pullularia* and *Polyspora* as between them. The same variation is seen in the physiological characters shown in Table 4. They were all serologically compatible indicating a close relationship to one another. The colour of the cultures on different media depended on chlamydospore development which again reflected growth rate. The rapidly growing isolates became black first. In no instance were any differences observed in the size and shape of the chlamydospores of all six cultures. The sprout-cells showed significant differences. There were two distinct types of these cells. There were short lenticular shaped cells found in isolates P1, P2, P5, and P6; and oblong cells found in isolates P8 and P9. In size there was no significant difference between isolates P1, P2, P5, and P6. These differed significantly in size from P8 and P9, but P9 differed significantly from P8. It will be noted that in all these isolates, the measurements of the sprout-cells fell below those given by Lafferty, namely, 9μ to 20μ with an average of 15μ. In making the sprout-cell measurements, cells at random positions were taken in the microscope field. The cells varied very greatly in size depending on their age. Thus in P1 they varied in length from $4{\cdot}1\mu$ to $12{\cdot}7\mu$.

The physiological variations were only of a minor character and could not be used for the separation of *Pullularia* from *Polyspora*. Flax was fully retted by each of the cultures in 7 days at 25°C.

The pathogenicity of these isolates on flax was tested in the greenhouse by spraying a suspension of sprout-cells in sterile water on to flax in pots at different stages of development, namely, seedling, half-grown, pre-flowering, flowering, seed-set, and near-ripe. The suspension was applied by means of a " de Vilbis " atomizer. After inoculation, the plants were kept in a moist chamber for four days. They were then transferred to the greenhouse and grown to maturity.

A preliminary test was made on Liral Crown flax at Canberra with isolates P2, P5, and P8 from Tasmania, Victoria, and New Zealand respectively. This test was made throughout the autumn and winter months and the plants were harvested in December. None of the plants showed any symptoms of browning and platings made of the unsterilized flax straw gave high yields of the *Pullularia-Polyspora* type of fungus, indicating that the inoculum was still present. The test was repeated in Tasmania on Concurrent flax during the summer under greenhouse conditions using all six isolates. Again none was pathogenic irrespective of the time of spraying.

From these studies it will be seen that cultures P8 and P9 could be distinguished from P1, P2, P5, and P6, on the basis of sprout-cell size and shape, and on the waxy-pink colour developed on potato slopes as against the dirty buff colour. However, P5 and P6 had both been identified as *Polyspora lini* and they have characters that correspond with P1 and P2 which were identified as *Pullularia pullulans*. Again P8 and P9, although having sprout-cells of the same shape, are significantly different in sprout-cell size. It would seem that the only basis for differentiation would be the shape of sprout-cells and the thallus colour of waxy-pink as against dirty-buff developed on potato slopes after 11 days incubation. On this basis cultures P8 and P9 (both identified as *Polyspora*) would be considered one group and cultures P1, P2, P5, and P6 (two were considered *Pullularia* and two *Polyspora*) would constitute another group. However, the similarity of all the other characters and the serological compatibility of all six cultures would suggest that they were all at least generically the same. That is to say, *Polyspora* is in reality *Pullularia* and the only specific difference shown by this investigation would be sprout-cell shape and colony colour on potato slope. This would make *Polyspora lini* either a species or sub-species of *Pullularia pullulans* such as *Pullularia pullulans* var. *lini*. It is interesting to note that Wakefield and Bisby (1941) made the following statements in their list of the *Hyphomycetes* in regard to *Polyspora lini*: "Described as one of the *Melanconiales* but grows as a Hyphomycete similar to *Pullularia*."

6. Discussion.

Typical symptoms of the browning disease appeared in flax crops in Tasmania, and from diseased tissue *Pullularia, Cladosporium,* and *Alternaria* were isolated. These fungi were also found to be the principal dew-retting organisms.

When cultures of *Pullularia pullulans* isolated from the diseased flax straw and dew-retted flax were compared with cultures of *Polyspora lini* isolated from browning-diseased flax from other parts of the world, they showed striking resemblance in microscopic structure, cultural, serological, and physiological characters as well as in their retting action. In two pathogenicity tests on flax all isolates of both fungi failed to produce any reactions; and it was impossible to separate the cultures of *Polyspora lini* from *Pullularia pullulans* on any of the above characters.

Martin (1929) suggested that many fungi have common developmental phases and the terms pseudosaccharomyces and pseudo-fumago are used for these early phases. He stated that "certain form genera have been described which have phases that are indistinguishable from the budding or fumagoid phases." The following are some of these listed by him: *Dematium pullulans, Fumago vagans, Kabatiella, Polyspora lini,* and *Aureobasidium.* It will be noted that these, except *Polyspora,* are recognized as synonyms of *Pullularia.* From the results of the investigation reported in this paper it appears that *Polyspora* might also be a synonym. The identification of *Polyspora* as *Pullularia* was rendered difficult by the fact that the original cultures of de Bary's *Dematium,* Lafferty's *Polyspora,* and Bennett's *Anthostomella* were not available to the writer. Final proof that *Polyspora lini* and *Pullularia pullulans* are identical will depend on the development of the ascigerous stage *Anthostomella pullulans* in all the cultures. All attempts so far made by the writer to obtain the ascigerous stage in these cultures have failed. It is interesting to note that, although all the isolates of *Polyspora lini* from different sources showed the development of the black chlamydospores in old cultures, Lafferty makes no mention of either the black pigment or the chlamydospores. He may have selected only non-pigmented strains, and this would be possible judging by the writer's experience with strain variation in *Pullularia.*

If *Polyspora* and *Pullularia* are identical, then the association of these fungi with browning disease of flax would be secondary. Bennett describes *Pullularia* as being "saprophytic or weakly parasitic, but non-pathogenic and is of promiscuous habits as regards host material." This is amply confirmed by what is known of the occurrence of *Pullularia.* Being a weak parasite, *Pullularia* can only attack when the host tissue is injured or resistance seriously lowered through very unfavourable environmental conditions for the host plant. This was observed in needle blight of conifers (Haddow, 1941), and forking of red pine, and the difficulty some workers have had in obtaining a positive reaction with flax. It is suggested that browning symptoms may develop through attack by *Pullularia* which may, or may not, be a species distinct from *P. pullulans.* This develops on the flax along with associated fungi when the plant is adversely affected by an unfavourable environment. The positive pathogenicity reactions claimed by Lafferty and others, and the failure by the writer to obtain any pathogenicity reaction on flax suggest that a very special set of environmental conditions might be necessary to favour the development of symptoms of browning. It is suggested that browning may be actually premature retting in the field. This possibility is now being investigated.

Lafferty and others maintain that browning is a seed-borne disease and have recommended various seed treatments. In spite of these precautions, browning symptoms have appeared in new areas that never produced flax before. This is in keeping with the view of the probable identity of *Polyspora* with *Pullularia.* The latter fungus being ubiquitous would render seed treatment a useless procedure. It will be recalled that in this investigation *Pullularia* occurred at about the same rate on seed from healthy crops as from diseased crops. The beneficial effect of seed treatment on germination in Petri dish cultures is apparently due to the removal of competing and antagonistic saprophytes. *Pullularia* was shown to be inimical to the germination of grass and peas, and although the mycelium of this fungus was found in the seed coats of grass and peas, it was shown to be non-pathogenic. The mycelium in the seed-coat of flax might be that of *Pullularia.*

7. Acknowledgments.

The writer wishes to thank Mr. A. V. Hill, Senior Research Officer of the Division of Plant Industry, C.S.I.R., Canberra, for completing the pathogenicity test at Canberra, and also acknowledges his indebtedness to Dr. Campbell Duncan, Medical Pathologist of the Commonwealth Department of Health, Hobart, for assistance in the serological studies.

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Browning of Flax and Excess Soil Moisture.

*By H. R. Angell, Ph.D.**

Summary.

Browning of flax is of minor importance in the flax-producing areas of Australia.

In an experiment that was made out-of-doors, browning occurred only in drums that were waterlogged. No disease whatever appeared in those that received moderate or small supplies of water.

1. Introduction.

An account by Lafferty (1921) of the browning and stem-break disease of flax included a full description, with illustrations, of the symptoms of the disease and the association of an organism, *Polyspora lini* Laff., with the brown lesions on the aerial parts of the plants. Also described were the behaviour of the organism in pure culture and experiments on its pathogenicity and on the control of the disease.

The extent of the occurrence in Tasmania of a disease that appeared to be indistinguishable from browning was investigated by the writer in March, 1943. Because the disease was generally distributed over 250 acres of peaty soil in five different fields and was not found in any other fields that were sown with seed from the same source, it appeared more likely to be due to some adverse soil condition than to a seed-borne organism. During December of the same year, it occurred in two fields near Colac, Victoria. It was previously observed in the experimental plots at Canberra, A.C.T., in 1942. In every instance the general symptom picture and the prevailing climatic conditions suggested that the disease was unlikely to be due to organisms that might be associated with the indefinite superficial lesions on the aerial parts of the plants. Platings were made from the roots of the Canberra plants, but the organisms that were isolated were only saprophytes.

In this paper a short account is given of an experiment that was made in drums out-of-doors at Canberra. The symptoms obtained on plants growing on soil that was waterlogged for three weeks previous to the appearance of the disease were the same as those that occurred in the field.

2. Methods and Results.

Over 200 four-gallon drums were filled with soil of uniform quality that was collected for the purpose at the experiment farm. Sixteen other drums were filled with another type of soil from the same farm, and sixteen others from the plots adjoining the laboratory. To every one of the drums was added an equal quantity of superphosphate. In one treatment (*a*) lime was added at the rate of about 20 tons per acre to each of sixteen drums. Other treatments were (*b*) lime plus magnesium sulphate, (*c*) magnesium sulphate, or (*d*) potassium nitrate. All the drums were randomized. Seed of the variety Liral Crown was sown on August 14-15, 1944. Germination and growth were satisfactory. Because of the prevailing dry weather, frequent watering was necessary; this was done directly with the hose. From October 23 to November 15, 32 drums containing only soil, and sixteen others

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to which lime was added, were kept waterlogged. Sixteen other drums were supplied with little more than sufficient water to keep them alive. To all the others, enough water was given for ordinarily good growth. On November 15, on the upper portion of one plant in a waterlogged drum, symptoms were observed that were reminiscent of those of browned plants in the field. The water on the surface of the soil in the drums was immediately drained off, and from that time until the plants were harvested the amount supplied was about the same as was given to all the others—excepting those that were being kept fairly dry. The plants in each of the drums in which the soil was previously waterlogged began in turn to develop symptoms of browning. The most prominent feature was the general browning and dying of individual plants in each of the 48 drums during the flowering and fruiting season. In Table 1 the number of plants in each of one lot of sixteen drums and the number that died from browning are set out. In addition to 26 per cent. of dead plants, there were several in each drum on which there were brown spots that varied in size from mere specks to blotches that merged to make the stems almost entirely brown from root to tip. The spots were superficial. Only in one of all the other drums did a few plants develop browning symptoms; the level of the soil was well below the rim, and apparently this encouraged too liberal watering. The crop in the waterlogged and control drums with which this paper deals was harvested on November 30, dried, and afterwards retted in an electrically heated, temperature-controlled tank. Retting was done in 48 hours. After drying in gaits the straw was stored for three months, and then scutched on a two-bladed wheel. There appeared to be but little, if any, difference between the fibre from the controls and that from the waterlogged plants.

Table 1.—Showing Number of Plants and Number Browned and Dead in Each of 16 Drums.

Pot Number.	Number of Plants.	Number Browned and Dead
20	124	29
21	108	19
22	95	44
23	145	54
24	116	18
25	175	35
26	114	25
27	..	..
30	84	35
31	156	15
32	102	2
33	78	30
34	107	39
35	103	45
36	175	25
37	174	68
Total	1,856	483 = 26%

3. Discussion.

In some of the flax-growing districts of the Commonwealth, water accumulates for a few weeks on some of the poorly drained soils if the rainfall is unusually heavy. The calcium content of these and adjoining areas is, as a rule, low. On these soils, flax that is, or should be, growing actively immediately before flowering is liable to the disease

known as withertop (Millikan, 1944). The tops of the plants bend over at 3 or 4 inches from the top, break, and wither away. In a few instances that have been noticed by the writer, plants that received too much water escaped withertop injury, and were later affected with browning.

Browning and dying of plants in irregular patches as described by Lafferty were observed by the writer in the Australian Capital Territory in 1942, and in Tasmania and Victoria in 1943. Withertop and browning occurred in the same area in the experimental plots at Canberra, the former in the wet areas before flowering, the latter after flowering began. The occurrence of the two diseases in the same field has not been noted by the writer in the flax-producing districts.

Under the conditions of the experiment with which this paper deals, browning occurred in drums that were waterlogged for three weeks previous to its first appearance. Removal of the excess water from the waterlogged drums as soon as symptoms were observed on one plant, and the maintenance of a good average supply thereafter, did not prevent subsequent development of the disease. In the field the writer observed that browning began after the excess soil water had disappeared. The association between excess water in fields and subsequent browning was not, however, apparent until after the results of the experiment in drums were known. Although in these experiments browning occurred in all drums that were too liberally supplied with water, it should not be assumed that in the field the disease is invariably associated with excess soil water. Were it so, browning would be distributed much more generally in some years in some of our flax-growing districts. The physical and chemical composition of the soil apparently exercise a controlling influence. In these experiments, it should be noted, lime did not modify the severity of the attack.

Up to the present time browning has occurred in only a few fields in Australia, and whether or not it is of much economic importance is doubtful. In two instances, the fibre from plants from badly browned fields was of better grade than was obtained from any other straw of the same diameter from the same mill (New and Searle, 1928). Comparison of the fibre from healthy and browned plants from the same fields was impracticable, mainly because of the difficulty of collecting enough really healthy straws for a retting experiment. On the contrary, fibre from browned plants from another district was of no value, but that from the apparently healthy controls was also quite poor owing to the adverse weather conditions that prevailed when the plants were young. The available evidence suggests that if a crop is satisfactory in other respects, it should not be degraded because of the occurrence of browning.

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The Moisture Content of Meat Extract.

2. A Quick Density Method for Its Determination.

*By Arthur R. Riddle, A.B., M.S.**

Summary.

The difficulties associated with finding the end-point in "finishing-off" meat extract are briefly discussed; the factors which have been responsible for lack of consistency and precision of measurement in previous attempts to use a density method for the determination of moisture content are examined; and an improved method is described which will give, in a few minutes, values for moisture content correct to within $\pm\frac{1}{4}$ per cent. of the values that would be obtained by the oven-drying or distillation-in-an-immiscible-liquid methods with which it is calibrated.

1. Introduction.

Meat extract is usually derived from the "soup" which results from the cooking of meat subsequently used for canning. This "soup" is concentrated by evaporation in both vacuum and open-type evaporators until the operator judges the extract to be of the desired moisture content, when further evaporation is stopped, samples are taken for laboratory determinations of moisture, and the completed extract "drawn" and packed, usually in large containers. On receipt of the laboratory determination of moisture content, the operator decides whether or not the extract to which it refers has to be returned to the evaporating pan for adjustment of the moisture level. The difficulty of knowing when to "finish-off" an extract for a specific moisture level is very real. Errors of judgment may give rise to considerable losses to the industry. Extreme cases have been known where extract has had to be retreated up to four times before the moisture level was satisfactorily adjusted. The desirability, therefore, of a method by which an estimation of the moisture content of an extract, good to at least ± 1 per cent. could be achieved in a few minutes, should be readily apparent.

All quick methods for the determination of water level, whether by measuring some physical factor such as density, refractive index, or electrical conductivity, must be calibrated with some standard method such as oven-drying or distillation in an immiscible liquid, even if that standard method gives purely arbitrary values, as was pointed out by Riddle (1944), in Part 1 of this series. The method discussed here, based upon the measurement of density, is one of several respecting which this laboratory intends to publish details, and does not rely on expensive scientific equipment, as some of the other methods do.

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The general principle involved in estimating moisture levels by a determination of density is not novel. In practice, however, the method has never given entirely satisfactory results, nor as much precision as is desirable. As a consequence, its use has been given up by several operators who tried it. Briefly, the density method depends on making a curve, similar to that shown in Fig. 1, connecting densities of standard dilutions of a number of samples of extract taken at various stages of evaporation with corresponding values of moisture content determined by oven-drying or by distillation in an immiscible liquid. This curve is used to determine the moisture level of an extract at any stage of evaporation by making a determination of density and referring to the curve for the corresponding moisture value. Since the method gave promise of great usefulness if it could be made to yield consistently accurate results, the experimental work of this laboratory was directed to (i) an examination of the variables concerned, since it was obvious that uncontrolled variables were responsible for inconsistency, and (ii) the possibility of improving instrumental methods essential to precision.

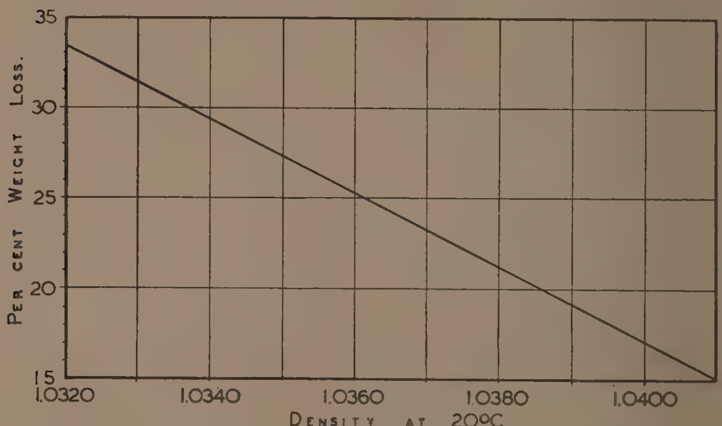

Fig. 1.—Per cent. weight loss—usually referred to as moisture content—obtained by the oven-drying of meat extract, as a function of density at 20°C. of a standard dilution as specified in the text.

For the purposes of this paper it is not necessary to give full experimental details; such as seem essential will be mentioned in their appropriate places. Following a discussion of the variables likely to be encountered in the use of this procedure and the factors affecting precision, an outline will be given of a method which, in a few minutes, will give results correct to within $\pm\frac{1}{2}$ per cent. of the values that would be obtained by the oven-drying or distillation methods with which it is calibrated.

2. Discussion of Factors Affecting Consistency and Precision of Determinations.

(i) *Determination of Density.*

Determinations of density made during the experimental work were done by both density bottle and hydrometer. While the former is preferable, its use would not be practicable in industry, nor is it necessary in order to achieve the accuracy of moisture estimations mentioned above. It is, however, necessary to stress that the hydrometer often met with in industry and used in some cases where this method has been tried, is totally inadequate. The range which has been found necessary in this laboratory is roughly 1·0325 to 1·0425. It is therefore desirable that the hydrometer employed should cover no more than this range, and that it be graduated to indicate density in grams per millilitre at 20°C. in accordance with standard practice—B.S.S. No. 718 (1936).

(ii) *Accuracy of Moisture Determinations with Which This Method is Calibrated.*

The density method is only as good as that with which it is calibrated. In the absence of a universally accepted and standardized method for the determination of moisture content in meat extract, as suggested by Riddle (1944), any quick method will, for the present, have to be calibrated with the method employed by the individual manufacturer. Since such methods may show overall variations of up to 3 per cent. in extreme cases between two determinations on one sample, it is desirable to replicate at least three times and use the arithmetic mean of the values obtained. This laboratory intends to publish, shortly, details of a drying oven and a drying-oven technique which give greatly improved results with very little spread between replicates.

(iii) *Plotting the Curve.*

Since the working range lies between roughly 15 per cent. and 30 per cent. moisture content, this range must be plotted on a sufficiently open scale to permit of the necessary accuracy. In Fig. 1 it will be seen that for variations of moisture content from 15 per cent. to 33·4 per cent., the density of the diluted extract varies only from 1·0320 to 1·0410.

(iv) *Temperature-Density Correction.*

In practice, the diluted extract will not, in most cases, be at the temperature for which the hydrometer is calibrated. Failure to recognize this can be responsible for very considerable inaccuracy. From Fig. 2, where hydrometer (20°C.) readings on one extract of approximately 23 per cent. moisture content, are plotted as a function of temperature, it will be seen that from 20°C. to 30°C. the density varies by approximately 0·0030 which, from Fig. 1, corresponds to an apparent shift in moisture content of approximately 6 per cent. Since the whole purpose of this method is to obtain a quick determination,

time cannot be wasted in bringing the diluted solution to the temperature for which the hydrometer was calibrated, even though such procedure would considerably simplify matters. A temperature-density-correction curve, the making and use of which will be more fully discussed in the next section, is essential.

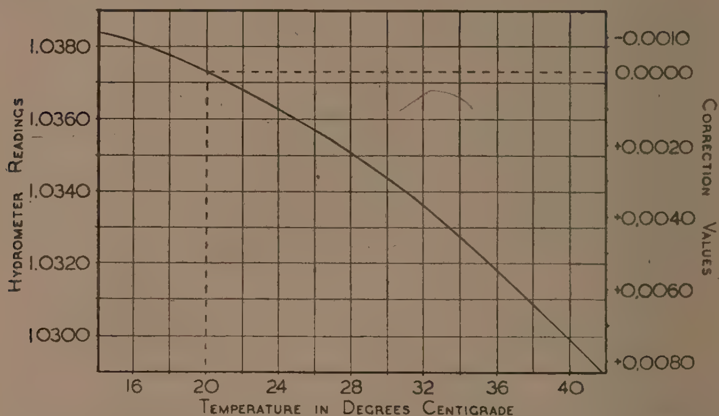

Fig. 2.—Hydrometer readings of density, as determined by an instrument giving density in grams per millilitre at 20°C., on a standard dilution of an extract of roughly 23 per cent. moisture content, as a function of temperature of the diluted extract, together with correction values to be applied to observed hydrometer readings when observations are made at temperatures other than 20°C.

(v) *Composition of the Extract.*

The composition of the extract markedly affects consistency for equal water content. For example, if the "soup" employed for concentrating has been derived from hearts, "skirts," bone, sinews, &c., as well as the boned-out muscle tissues usually employed, a much "stiffer," more gelatinous extract results for the same moisture content than when the "soup" is derived from boned-out muscle tissue only. "Soup" so prepared might be concentrated to a point where its consistency would suggest a moisture content of 20 per cent. on the basis of ordinary extract, yet possess a moisture content of 30 per cent.

In cases where extracts are prepared from mutton or mixtures of mutton and beef, it has been found that the density-moisture content curve for beef is not strictly applicable. It is therefore necessary, if accuracy is required, to plot separate curves for each type of material from which the "soup" is derived. *If this method is to operate at its best, it is essential that the composition of the material from which the "soup" originates, the temperature and time of cooking, and the subsequent procedures leading to the completed extract, be standardized.*

(vi) *Avoidance of Vapour Pressure Equilibration.*

Changes in water content of extracts can occur very rapidly when the vapour pressure of the extract is not in equilibrium with the air with which it is in contact. Experiment has shown that when this difference is marked, the change can be sufficiently rapid to affect

moisture-content estimations very appreciably if every care is not taken to avoid such interchanges. From the time a sample is taken, it is desirable to reduce the period of exposure to air to the essential minimum.

3. The Improved Technique.

(i) *Dilutions.*

25 g. of extract is weighed into a beaker, water added to bring the contents of the beaker to 250 g., and the extract dissolved by stirring until homogeneity of density may be justifiably assumed. This solution is then poured into the cylinder, and readings made of temperature, and density as measured by the special hydrometer.

Extensive sampling of the extract from various parts of the evaporating pans to which this laboratory had access, indicated a remarkable uniformity in moisture content of the extract over the whole of the pan. Under these conditions it is sufficient to take one sample of extract for any one determination.

(ii) *Constructing the Density-Moisture-Content Curve.*

As suggested earlier, it is desirable to have a separate calibration curve for each different type of extract manufactured. Under normal conditions where only beef extract of standard composition is made, only one curve correlating moisture content with density of the diluted extract is needed. The curve shown in Fig. 1 was plotted from determinations made over a long period, including the earlier ones when precision of determination was not nearly as good as it became later.* Despite this fact, all determinations made with the improved technique, with the exception of some of the very early ones, are well within $\pm\frac{1}{2}$ per cent. of the value obtained by the oven-drying procedure with which the density method is calibrated.

The relationship between density and moisture content over the operating range can, for all practical purposes, be regarded as linear. It is therefore suggested that, instead of plotting a curve from a number of values obtained from samples of varying moisture content, it will be sufficient to construct the curve from the mean of well-replicated determinations on two samples taken at different stages of evaporation by plotting the two points obtained thereby, and passing a straight line through them. Actually the accurate determination of one point only will suffice, since the second point may be computed.

(iii) *The Temperature-Density-Correction Curve.*

It is very desirable that the temperature-density-correction values be obtained experimentally for each individual hydrometer. This empirical value will then cover all temperature factors influencing the instrument, including those of volumetric changes in both it and the liquid. A temperature-density-correction curve sufficient for all practical purposes can be made readily by determining the densities

* A statistical analysis of the data from which Fig. 1 was plotted, done by Mr. E. W. Hicks, of the Division's headquarter's laboratory, at Homebush, yielded a regression line $Y = 98{\cdot}67 - 2040x$ where $Y =$ per cent. weight loss, and $x = (\text{density} - 1)$, with a standard deviation of $0{\cdot}363$ per cent. water.

on one sample of diluted extract of a moisture content preferably in the neighbourhood of that at which it is desired to "finish off" the extract, at temperatures covering the maximum range likely to be experienced in the diluted extract, say 15°C. to 40°C. A curve can then be plotted of hydrometer readings against temperature. From this, another curve, or a table, can be prepared to give the plus or minus corrections to be applied to the original hydrometer readings, to adjust them to 20°C. for which the hydrometer is calibrated. For example, from the curve in Fig. 2, prepared in this laboratory from data obtained on an extract of approximately 23 per cent. moisture content, another curve of corrections plotted against temperature could be made. For convenience these corrections may be shown on the same graph as in Fig. 2.

Theoretically, a number of temperature-density-correction curves for extracts of varying moisture content would be needed. In practice, however, the correction values would be so slightly modified that they would not appreciably affect the value of moisture content.

Hydrometer readings of density made in this laboratory on various diluted extracts, when corrected as indicated above, agreed with determinations made with a density bottle at 20°C. to within $\pm 0 \cdot 0002$. With an hydrometer of more open scale than the one used in these determinations, these limits might be further narrowed down.

(iv) *Using the Curves.*

When an operator feels that the extract is approaching the desired moisture content, a sample is taken, diluted as specified above, temperature and density readings made, the temperature-density-correction determined and applied to the hydrometer reading, and the moisture content read from the calibration curve. Thus, supposing a reading of 1·0336 is made at 32°C., then from Fig. 2 the correction value necessary to adjust the reading to 20°C. is $+0 \cdot 0037$. By adding this to the reading of 1·0336, the corrected value for 20°C., at which temperature the calibration curve was made and the hydrometer calibrated, is 1·0373, which from Fig. 1 is seen to correspond to a moisture content of 22·7 per cent. in terms of the method employed for making the oven-drying determinations for this curve.

4. Conclusion.

It must be stressed that this method should not be regarded necessarily as one to replace the oven-drying determination on the completed extract. Its function is purely to determine quickly the end-point at which the extract is to be "finished-off."

Again, the curve in Fig. 1 must not, of course, be used in industrial practice, since it has been made from data obtained on one standard procedure of making extract, and would not, of necessity, fit the conditions existing in another plant. It, and the temperature-density-correction curve, with details affecting their construction, afford all the guidance necessary to enable the making of the essential curves to fit the need of any individual manufacturer.

5. Acknowledgments.

Grateful acknowledgment is made of the generosity of the Queensland Meat Industry Board which, in addition to providing the laboratories and certain equipment, makes an annual contribution to the work of the Council's Food Preservation and Transport Division in Brisbane; to Swift Australian Co. (Pty.) Ltd. for co-operation in placing at the Council's disposal manufacturing facilities without which this work could not have been accomplished; to Messrs. H. A. McDonald and H. J. E. Prebble for certain laboratory determinations; and to Miss J. E. O'Driscoll for draughting work.

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Manna-Formation in *Myoporum platycarpum* R.Br.

*By Eileen E. Fisher, M.Sc., Ph.D.**

Summary.

Three organisms, a species of yeast, and two bacteria, which have been isolated from the inner bark of *Myoporum platycarpum*, are considered as the possible cause of manna-formation in this species. However, the evidence obtained by the inoculation of normal trees is negative and suggests that these organisms merely live saprophytically on the manna.

A detailed description is given of the two bacterial species isolated.

1. Introduction.

The formation of an exudate by *Myoporum platycarpum* was first recorded by Bennett (1882), but it was Maiden (1892) who showed this exudate to contain mannitol. He examined a specimen of solidified exudate, the so-called manna, which had been collected by the Sir Thomas Elder Expedition, and reported a mannitol content of 89·7 per cent. Although Maiden regarded it as the perfect substitute for commercial European manna, which is obtained from *Fraxinus ornus*, no further investigation of this material appears to have been made until quite recently, when the increasing importance of mannitol to industry made it seem desirable to determine the value of this exudate as a source of mannitol. Its re-examination was commenced by the Division of Industrial Chemistry of the Council for Scientific and Industrial Research which has in hand the examination of the yields

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of exudate obtainable from single trees, the variation of yield with season, and the development of a suitable process for the isolation of mannitol in a state of purity.

The unpublished results of Hatt and Hillis show that the mannitol content of the liquid exudate is variable but is most often in the range 15-20 per cent.; 60-70 per cent. of the total solids content of the exudate consists of mannitol. A rough survey of trees in districts surrounding Red Cliffs, Yarrara, and Merbein in N.W. Victoria showed that of some 1,000 trees inspected about 7 per cent. yielded manna. The incidence of exuding trees appeared to be highest in areas of assured water supply.

M. platycarpum unlike *F. ornus* cannot be made to bleed by mere incision of the bark.

Helms, the collector on the Elder expedition, believed this bleeding to be caused by "insect-bores," but our observations indicate that although borers commonly occur in the wood of *M. platycarpum*, manna production is not always associated with these insects. In the absence of any satisfactory explanation of this phenomenon, consideration is given here to the micro-organisms which grow on the inner bark of exuding trees. Isolations made in the laboratory, as well as those made directly from exuding trees, have yielded repeatedly, three organisms: a species of yeast, and two bacteria, a gram-positive and a gram-negative, which have usually been isolated together.

Considering that mannitol has been formed from fructose by bacterial action (Peterson and Fred, 1920*a*, 1920*b*), particular attention is paid to the bacteria isolated as a possible cause of the exudation. However, cultures grown in solutions (peptone-water and Czapek's Dox) containing one of the following sugars: glucose, lactose, maltose or sucrose, did not produce any mannitol; fructose was not available in sufficient quantity for this sugar to be tested. Furthermore, the unpublished results of Hatt and Hillis show that mannitol is present in the leaves and bark of non-exuding trees to the extent of 2·3 per cent. and 0·6 per cent. dry weight respectively. This suggests that the "manna" is not formed by the fermentation of sugars in the plant sap.

2. Description of Exuding Trees.

These trees are most active in spring when a white frothing liquid may be seen exuding from the trunk and branches (Plate 1, Fig. 3); later this exudate dries into a solid mass, often in the form of stalactites (Plate 1, Fig. 2).

The age of exuding trees is very variable, some are approximately 9-11 years (Plate 1, Fig. 1), while others measuring 6½ feet in girth would be approximately 45 years old.

A microscopic examination and comparison of sections cut through exuding and non-exuding branches showed a complete disappearance of starch and accumulation of gum and tannin in the medullary ray and wood-parenchyma cells of exuding specimens. Furthermore, the phloem is considerably modified, parenchymatous cells (Plate 2, Fig. 1) which contain large quantities of gum and tannin are developed to the almost complete exclusion of the sieve-tubes found in normal phloem (Plate 2, Fig. 2).

3. Description of Bacteria.

Growing in association in the inner bark of exuding trees are two bacteria which may be described as follows:—

(i) Gram-Positive.

(a) Morphology.

Culture grown on malt-agar for 24 hours consisted of gram-positive rods with rounded ends, which occurred in chains. The length of rods varied from $1 \cdot 7\mu$-$10 \cdot 2\mu$, average length $3 \cdot 8\mu$, with a diameter of $0 \cdot 57\mu$. In 6-day cultures, some cells stained irregularly, and in older cultures some cells gave a completely gram-negative reaction. The motility of the organism was tested in cultures grown in acetic acid broth and in glucose-peptone water. Motility did not occur in either of these media after 24 hours' growth, but after 31 hours in glucose-peptone water a few rods were motile, and after 48 hours practically all moved across the field with a slow swaying motion. This is a non-sporing organism, cultures being killed by heating to 60°C. for 30 mins.

(b) Cultural Characters.

All cultures were grown under anaerobic conditions and unless otherwise stated the incubation temperature was 24°C.

Malt-Agar Colonies.—No growth after 24 hours' incubation, but after 72 hours the colonies measured approximately 83μ ($0 \cdot 08$ mm.) in diameter. They were transparent, circular, with a fimbriate edge, flat and smooth. After 96 hours they became translucent and measured approximately 130μ ($0 \cdot 13$ mm.) in diameter, the edge became lobate and the surface rough.

Malt-Agar Stroke.—Glistening, filiform, white growth after 72 hours' incubation.

Nutrient-Agar Stroke.—The growth is similar to that on malt-agar, excepting that the surface is dull.

Nutrient Broth.—No turbidity or surface growth, but after 14 days' incubation, a copious white powdery deposit was formed.

Acetic Acid-Broth.—The scanty growth was similar to that in nutrient broth, but less deposit was formed.

Gelatin.—No growth occurred after incubation for four weeks at 20°C.

Litmus-Milk remained unchanged.

Potato-Medium.—A copious glistening slimy white growth was formed after 11 days' incubation.

(c) Physiological Characters.

Relation to Free Oxygen.—This organism is a facultative aerobe, growth being more copious when the cultures are kept under anaerobic conditions. The first isolations made from the bark of exuding trees yielded, under aerobic conditions a mixture of gram-positive and gram-negative organisms, the gram-positive was only grown separately anaerobically. More recently, however, pure cultures of the gram-positive organism have been isolated aerobically.

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Action on Nitrates.—A reduction of nitrate to nitrite was demonstrated by a red colour reaction, after adding a few drops of a solution of 5 grams α-naphthylamine in 1 litre 5 N acetic acid, and of a solution of 8 grams sulphanilic acid in 1 litre 5 N acetic acid, to an 11-day nitrate-broth-culture.

Indole Production.—Eleven-day peptone-cultures gave negative results with the Ehrlich Böhme technique.

Carbohydrate Reactions.—The organism was grown in peptone-water containing 1 per cent. Andrade's Indicator and 1 per cent. of the carbohydrate to be tested. The H-ion concentration was adjusted to pH 7·6. Inoculations were made in duplicate or triplicate. In no instance was gas produced, but, in some, acid was formed and these results are tabulated below.

TABLE 1.

—	Glucose.	Mannitol.	Saccharose.	Mannose.	Lactose.	Laevulose.	Xylose.
Gram + ve ..	+	+	+	+	−	+	−
Gram − ve ..	+	−	−	+	−	+	+
Mixture	+	+	+	+	−	+	+

+ = acid ; − = no acid, no gas.

Acid was formed from glucose and laevulose after 24 hours' incubation; with mannose, acid only appeared after 11 days, and mannitol and saccharose required at least 16 days' incubation.

Comparison of Growth on Various Culture-Media.—The usual bacteriological media were used, including nutrient agar, Czapek's agar, whey-agar, beerwort-agar and 2 per cent. malt-extract-agar. The last-mentioned medium produced best growth but this was not profuse. Moreover, growth was not improved by using an agar-medium containing an extract of *Myoporum*. The extract was made by soaking overnight in 500 cc. water, 200 grams of bark from *M. platycarpum*. This was filtered through a Seitz filter and then mixed in equal parts with a 4 per cent. agar solution which had been autoclaved.

Vitality on a Culture-Medium.—The organism was still alive after 12 months on malt-extract-agar when kept under anaerobic conditions. When grown aerobically cultures remained alive for 7 weeks, but not for 3½ months.

(*ii*) *Gram-Negative.*

(*a*) *Morphology.*

This organism is smaller than the gram-positive. The short rods with rounded ends after 24 hours' growth on malt-agar measured from $1{\cdot}2\mu$-$1{\cdot}7\mu$ in length and approximately $0{\cdot}57\mu$ in diameter. They usually occurred singly and they gave a uniformly negative reaction with gram's stain. Motility was observed in acetic acid-broth after 21 hours' incubation, and peritrichous flagella (Plate 1, Fig. 4) have been demonstrated by Gray's method of staining (Conn and Wolfe, 1938). Best results were obtained from cultures which were grown on

malt-agar for 24 hours and then suspended in distilled water for 25-35 minutes. It is a non-sporing organism, cultures being killed by heating to 60°C. for 30 minutes.

(*b*) *Cultural Characters.*

All cultures were grown under aerobic conditions and, except in the case of gelatine, the incubation temperature was 24°C.

Malt-Agar Colonies.—No growth after 24 hours' incubation but after 48 hours the colonies measured approximately 50μ (0·05 mm.) in diameter. They were transparent, circular, with entire margin, flat and smooth. After 72 hours they became translucent and measured approximately 166μ (0·16 mm.) in diameter, the margin becoming undulate. After 96 hours the colonies became slightly raised in the centre.

Malt-Agar Stroke.—Glistening, filiform cream growth after 48 hours' incubation.

Nutrient Agar Stroke.—After 72 hours' incubation a dull translucent filiform growth occurred.

Nutrient Broth.—No turbidity or surface growth, but a flocculent deposit, which did not disappear completely on shaking, was formed after 72 hours' incubation.

Acetic Acid-Broth.—A copious flocculent deposit was formed after 72 hours' incubation and 2 days later the broth became uniformly turbid. After 7 days' incubation a ring of growth which disintegrated completely on shaking was formed around the wall of the tube. After 3 weeks' incubation this surface growth formed a thick pellicle which disintegrated on shaking.

Gelatin.—No growth occurred after incubation for 4 weeks at 20°C.

Litmus-Milk remained unchanged.

Potato-Medium.—A glistening, yellow growth occurred after 11 days' incubation. Growth was better on untreated potato pieces than on those which had been treated with sodium bicarbonate.

(*c*) *Physiological Characters.*

Relation to Free Oxygen.—This organism is a facultative anaerobe, growing very feebly when kept under anaerobic conditions.

Action on Nitrates.—A reduction of nitrate to nitrite has been demonstrated in an 11-day culture.

Indole Production.—This was tested in the same way as for the gram-positive organism and negative results were obtained.

Carbohydrate Reactions.—These results are recorded in Table 1. Unlike the gram-positive, this organism ferments the pentose sugar xylose, producing acid after 7 days' incubation. Acid is formed from glucose after 24 hours and from laevulose after 3 days' incubation.

Comparison of Growth on Various Culture-Media.—As for the gram-positive organism, malt-extract-agar proved to be most favourable.

Vitality on a Culture-Medium.—When grown under aerobic conditions this bacterium remained alive for 9 months on malt-extract-agar.

4. Inoculation Experiments.

Pure cultures of the micro-organisms isolated from the inner bark of exuding trees have been inoculated into normal non-exuding trees. This experiment was carried out at Red Cliffs and at Yarrara. Sixty-seven trees were used and three or four inoculations were made in each tree. A T-shaped incision was made in the bark, which was then moistened with sterile water, the inoculum was introduced, and the wound was bound up with tape soaked in grafting-wax. In the case of six trees, which were used as controls, this procedure was followed but no inoculum was introduced. Thirty-three trees were inoculated with a mixture of gram-positive and gram-negative bacteria, five with the gram-positive and fifteen with the gram-negative only. The yeast together with a mixture of the gram-positive and gram-negative bacteria provided the inoculum for three trees, and five were inoculated with the yeast only.

For the purpose of detecting the presence of any non-culturable infective principle, another ten trees were inoculated in the same manner, but using as the inoculum a fragment of the inner bark from an exuding tree.

These experiments were carried out at various seasons, in January, 1943, and again in June, 1944, at Red Cliffs, and in November, 1943, at Yarrara. During the 9-26 months since these inoculations were made no positive results have been obtained.

5. Conclusion.

The fact that a species of yeast and two bacteria are associated with manna-production in *M. platycarpum* is interesting, but until inoculation experiments yield positive results this phenomenon cannot be attributed to these organisms. The evidence suggests rather that they live saprophytically on the manna, and the cause of the exudation remains obscure.

6. Acknowledgments.

I wish to thank Mr. Moss of the Lands Department and his son for their assistance in carrying out the inoculation experiments at Red Cliffs. I am also grateful to Mr. McLeod, forest officer at Yarrara, for his help.

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NOTES.

Size Distribution of Particles from Dust Storms.

(*Contributed by R. V. Pavia, B.Mech.E.**)

The size of air-borne dust particles is a factor in the design of aircraft engine air cleaners, which is being investigated by the Division of Aeronautics. Opportunity was therefore taken to examine the size distribution of red dust from storms which passed over South East Australia on November 19 and December 16, 1944.

The samples were collected at Geelong (Victoria) where the dust had been brought down by rain on previously cleaned concrete. They were sized by sedimentation in water, extracting pipette samples at various depths and times. The method is described by Robinson (1922)†.

The results are summarized in the table below:—

Size in Microns.	Percentage by Weight less than Size.	
	19.11.44.	16.12.44.
1	4	·8
2·5	11	4·5
5	24	16
10	43	37
20	67	63
40	85·5	85·5
80	96·5	95·5
150	99·2	99·0

These results show that particles up to one-fifth mm. (200μ) can be carried for considerable distances in a storm, and an appreciable amount of dust is very fine (less than 1 micron).

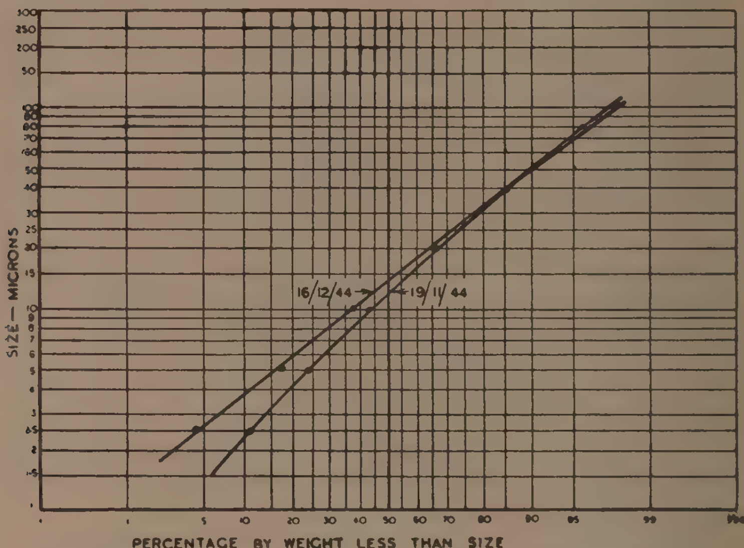
If the figures are plotted on logarithmic-probability paper as in Fig. 1, it is seen that half the weight of the dust is made up of particles that are less than 12-14 microns. The figures for the two storms plot close to straight lines on this type of paper, which indicates that the size distributions are nearly statistically "normal, skew".

The problem of designing filters which, within the physical limitations of an aircraft engine intake, will remove a high percentage of the dust from the air without clogging or excessive pressure drop is made much more difficult by the presence of such large amounts of fine dust.

* An officer of the Council's Division of Aeronautics.

† Robinson, G. W. (1922).—A new method for mechanical analysis of soils and other dispersions. *J. Agric. Sci.* 12: 306.

The coarser particles may be readily eliminated by methods depending on the inertia of the particles themselves but the smaller grains must be removed by filtration through dry or oiled pads.



SIZE DISTRIBUTION OF RED DUST FROM STORMS

FIG. 1.

Winter School in Soil Science.

A Winter School in Soil Science will commence at the Waite Institute, Adelaide, on August 20, under the auspices of the University of Adelaide and the Council for Scientific and Industrial Research. This will be the second meeting of this type—the first having been held in August, 1939, just before the outbreak of war. The School will be open to all workers in the field of soil science who are accredited by Universities, State and Commonwealth departments, the Council for Scientific and Industrial Research, or other organizations.

It will consist partly of lectures on established principles and recent advances and partly of conferences on a number of technical subjects requiring full discussion. A number of lectures will be given on soil surveying, soil physics, and soil chemistry. Conferences will be held on soil formation, soil classification—on both a regional and a local basis, land-use, ecology and soil type, soil fertility, soil-water relations, and soil structure. A field excursion lasting one day has been arranged.

Many of these subjects will have a direct bearing on the mapping of soils for post-war settlement or on the maintenance and improvement of soils especially on irrigated or eroding land.

The School will occupy ten days. Any one proposing to attend or wishing to make inquiries or suggestions regarding the programme is asked to get in touch with Dr. T. J. Marshall, Waite Institute, Private Mail Bag, Adelaide, who is acting as secretary of the Winter School. Arrangements for conferences are not easily made under present conditions, and early notice from intending visitors would be appreciated.

Soils and Irrigation Extension Service.

The Soils and Irrigation Extension Service, at the C.S.I.R. Irrigation Research Station, Griffith, New South Wales, has now been in existence for almost two years. It was formed in 1943 following a request to C.S.I.R. by the New South Wales Minister for Agriculture, and the Under-Secretary of the New South Wales Department of Agriculture, for the Research Station to undertake temporarily a specialized extension service in soils and irrigation practices on the Murrumbidgee Irrigation Areas. The present arrangement will come up for review during 1946.

The staff of the Service comprises the Officer-in-charge, Mr. R. R. Pennefather, together with three research officers, and a secretary, all of whom are graduates in agricultural science.

The rapid decline of plantings in the M.I.A. in recent years has caused serious concern, and as a result of its investigations, the Research Station at Griffith has amassed considerable information on the factors associated with this decline and the steps which may be taken to alleviate it. Many of the problems that have occurred are associated with excess soil water and salting, and the S.I.E.S. is endeavouring to translate the results of research into farm practice.

At the outset, the Service had before it the following aims:—

(*a*) improving soil and irrigation management methods on farms where there is potential danger for those already showing signs of deterioration but which are deemed saveable;

(*b*) improving the planning and management of replanted and newly-planted areas;

(*c*) reclaiming damaged land.

In its work, the Service lays stress on the value of farm visits and these occupy a large proportion of each officer's time. Coupled with these visits are field days and extension schools carried on in collaboration with the Settler's Extension Groups. Press articles, radio broadcasts, and a special "Farmers Newsletter" issued periodically, are among the vehicles used for the dissemination of information. Other publicity channels such as theatre slides, posters, and circulars are also used.

The Service has been notable in achieving the full co-operation of all the chief organizations interested in the well-being of irrigation farming on the M.I.A. and it is financed by contributions from C.S.I.R., the New South Wales Department of Agriculture, the Rural

Bank of New South Wales, the Water Conservation and Irrigation Commission, the Leeton Cooperative Cannery Ltd., the Griffith Producers' Cooperative Company Ltd., the Leeton Fruitgrowers' Cooperative Society Ltd., and the Yenda Producers' Cooperative Company Ltd.

The C.S.I.R. staff works in close association with the officers of the New South Wales Department of Agriculture stationed in the Areas, who retain full responsibility for extension work on the horticultural, as distinct from the soils and irrigational, side.

Scientific Liaison and Information Bureau.

As from April 17, the Council took over the Scientific Liaison Bureau with its existing staff, and this Bureau has now been incorporated with the Information Section in Head Office in a body to be known as the Scientific Liaison and Information Bureau. Mr. J. E. Cummins, who was seconded from the Information Section in March, 1943, to become Director of the Scientific Liaison Bureau, has now returned to C.S.I.R. as Director of the new body. The former offices of the Scientific Liaison Bureau in Melbourne and Sydney will be maintained for the time being.

New Divisions in National Standards Laboratory.

The former three sections of the National Standards Laboratory have recently each been converted into a Division, known as—the Division of Metrology, the Division of Electrotechnology, and the Division of Physics. The former Officers-in-charge, namely, Mr. N. A. Esserman, Dr. D. M. Myers, and Dr. G. H. Briggs respectively, are now Chiefs. The three Divisions will continue to have their headquarters at the National Standards Laboratory.

William Farrer Centenary.

On April 3, 1945, Australia celebrated the 100th anniversary of the birth of one who has been described as its greatest benefactor—William James Farrer. Certainly no one in Australia has contributed so directly to the wealth of the nation, and it is probable that we do not yet recognize the extent of the debt we owe to him.

Farrer commenced his wheat breeding researches in New South Wales in 1885, at a time when our wheat varieties were of inferior quality and when yields were so erratic as a result of the ravages of rust and drought that wheat had to be imported to meet local requirements. The phenomenal increase in the yield per acre and on the total yields for wheat produced in New South Wales and in Australia for several decades from 1910 onwards was a direct result of Farrer's pioneering work. Farrer's wheats over a period of years averaged up to 6 bushels an acre more than the old varieties. Farrer commenced his work in a new and uncharted field. He was neither trained nor experienced as an agriculturist, yet by his painstaking work, his careful observations and, above all, his intelligent interpretation of those

observations, he gave this country wheats which resulted in an extension of the wheat belt, wheats of better yielding capacity, and wheats which permitted development of an export trade on the world's markets.

Not only did Farrer work on the problem of drought and disease resistance, and on such special qualities as in the case of Federation which would permit the use of the stripper, but he was specially concerned also with the development of quality in wheat. He had as one of his objectives the production of a wheat which would provide a flour for making the loaf of bread of higher food value because of its increased protein content. Such an achievement, he considered, would be a direct contribution to a higher standard of living for the community.

Farrer was a member of the New South Wales Department of Agriculture from 1898 until his death on April 16, 1906. He was a pioneer investigator in wheat breeding research. Although a graduate of the University of Cambridge and trained as a surveyor he had little in the way of experience or training for the work to which he devoted his life. His mind, however, was one of exceptional vigor and originality, although the casual observer was inclined to regard him as an unpractical theorist. His methods, nevertheless, were eminently successful. His ideals and his objectives were clearly and constantly before him. His most spectacular result was the production of the wheat variety Federation, a variety which even 25 years after his death was widely cultivated in Australia.

Soon after his death in 1906, a public meeting resulted in the formation of the Farrer Memorial Trust. Funds were collected and are now administered by the Trust in the award of scholarships for research on wheat problems. A bronze bust of Farrer was erected in Monaro-street, Queanbeyan, in 1935. It bears an inscription in Farrer's own words, "I want to think that, when the end comes, my life has not been wasted." A few miles away at Lambrigg, overlooking the scene of his early labours, the Commonwealth Government has erected a memorial to his memory as "an enduring token of the gratitude of a nation to a great man of science."

Farrer's work still goes on. During the last 40 years other plant breeders and other investigators have made their contributions to the national welfare, but Farrer's life and work should be a constant source of inspiration to us all. Truly may he be regarded as a great Australian.

Review.

"MODES OF SPREAD OF *Streptococcus agalactiae* INFECTION IN DAIRY HERDS. A REPORT ON CO-ORDINATED OBSERVATIONS ORGANIZED BY THE AGRICULTURAL RESEACH COUNCIL OF THE UNITED KINGDOM."

(Review Series No. 2 of the Imperial Bureau of Animal Health, New Haw, Weybridge, Surrey, England, 1944, pp. 28. Price 3s. Obtainable from the Central Sales Branch, Imperial Agricultural Bureaux, Agricultural Research Building, Penglais, Aberystwyth, Wales.)

In 1941 the Agricultural Research Council of the United Kingdom initiated a series of co-ordinated field and laboratory investigations into bovine mastitis. One part of these investigations dealt with the mode of spread of *Streptococcus agalactiae* infection and the cause of

its persistence in dairy herds, and the present report, which has been published by the Imperial Bureau of Animal Health, gives the results obtained. The investigations were carried out by eight principal research workers at five centres including the Council's Experimental Station at Compton, the dairy research institutions at Reading and Ayrshire, and agricultural Advisory Centres at Leeds and Wye.

The recorded results of the investigations are summarized as follows. Of 16,482 samples of milk drawn from the cattle in twenty dairy herds scattered over an area extending from Ayrshire to Kent, *Str. agalactiae* was isolated from 38·8 per cent. Of 5,433 swabs taken from the external surface of teats of cattle in nine of these herds, *Str. agalactiae* was isolated from 23·1 per cent.

When these milk samples from these nine herds were examined at approximately weekly intervals over periods varying from 2½ to 6 months, the proportion of cows which yielded *Str. agalactiae* in the milk at one time or another varied from 35·6 per cent. to 100 per cent. The proportion of cows that showed the presence of the streptococcus on the exterior of the teats at one time or another varied from 45·7 per cent. to 100 per cent.

The results of the tests on the individual cattle within these herds varied so widely from one weekly test to another, that no one test would have given a correct picture of the distribution of the milk or teat infections.

A proportion of the animals were found to be persistent skin carriers and this carriage was frequently associated with the presence on the teats of abrasions or sores.

Str. agalactiae was isolated from a high proportion of the milkers' hands and from objects in the cow shed which they were likely to touch.

These findings are discussed and the opinion is expressed that it is surprising any success has been recorded in the control or elimination of mastitis by methods used. They go far to explain the frequent failures and breakdowns. However, recent advances in chemotherapy, including the synthesis of many new skin disinfectants, seem to offer practicable methods of control and possibly elimination of infection. The work is being continued along these lines.

Scientific workers as well as control and advisory officers will want to read and study this report. It confirms and extends the results that have been obtained by research workers in Australia, and it emphasizes again the impossibility of obtaining a true picture of the existence and spread of infection in a herd unless frequent bacteriological examinations are made. The concluding paragraph of the report is very pertinent for those interested in the control of the disease in Australia. It is as follows:—

"A major difficulty will probably be to devise any technique that is effective without being, or seeming to be, beyond the compass of any ordinary commercial herd. There can be no doubt that any successful attack on this disease will demand the continuous and whole-hearted co-operation of the dairy farmer and all members of his staff, as well as of veterinarians. It seems very unlikely that we shall succeed in eliminating this, or other diseases, from our herds unless we make far

more vigorous efforts to train those of our agricultural workers who have the care of livestock in the principles that underlie the control of infective disease, and secure their willing and intelligent co-operation in procedures which, to the uninitiated, seem mysterious, laborious, and of doubtful value."

Recent Publications of the Council.

Since the last issue of this *Journal,* the following publication of the Council has been issued:—

Bulletin No. 183.—"Experimental Determination of the Influence of the Red-legged Earth Mite (*Halotydeus destructor*) on a Subterranean Clover Pasture in Western Australia," by K. R. Norris, M.Sc.

The red-legged earth mite is a pest confined to parts of South Africa and southern Australia. In both countries it causes considerable losses in the production of vegetables, but in Australia it is also of great importance because of the damage it inflicts on pasture legumes, particularly subterranean clover. As a pasture pest it is most serious in the south-west of Western Australia. The experiments described in the present Bulletin extended over three years and were designed to give a more accurate estimate than hitherto available of the effect of the mite on pastures.

Observations showed that the mites caused considerable reduction in the foliage and seed yield of subterranean clover. The weight of individual seeds was also reduced by the attack. A secondary effect of the mite attack, particularly in the third year of the trial, was that the reduction in subterranean clover yield was associated with a reduced yield of Wimmera ryegrass. The direct effect of the mite on the ryegrass is probably not important; the lower yield may be due to the reduced contribution to soil fertility made by the clover. Other types of annual clover are little affected by mites.

No effect was produced by mite attack on the total yield of pastures not seeded with subterranean clover, but pronounced effects on total yield were produced where subterranean clover had been sown.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 184.—"Fellmongering Investigations," by F. G. Lennox, D.Sc., Margaret E. Maxwell, M.Sc., and W. J. Ellis, A.S.T.C.

Bulletin No. 185.—"Studies on the Mitchell Grass Pasture in South-Western Queensland. 2.—The Effect of Grazing on the Mitchell Grass Pasture," by R. Roe, B.Sc. (Agric.), and G. H. Allen, Dip. Agric. (Lawes).

Bulletin No. 186.—" The General Ecological Characteristics of the Outbreak Areas and Outbreak Years of the Australian Plague Locust (*Chortoicetes terminifera* Walk.)," by K. H. L. Key, M.Sc., Ph.D.

Bulletin No. 187.—" Foundry Sand Resources of South Australia," by H. S. Cornelius and H. A. Stephens, B.Sc.

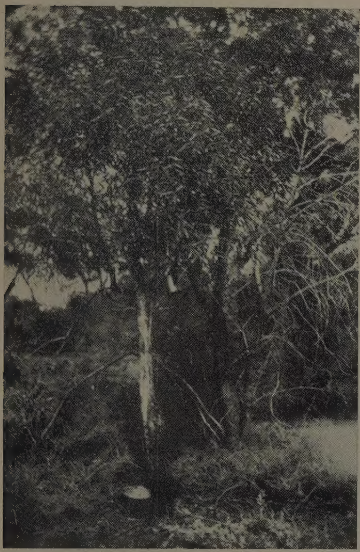
Bulletin No. 188.—" A Soil, Land-Use, and Erosion Survey of County Victoria, South Australia, including the Hundreds of Belalie, Whyte, Reynolds, and Anne and part of the Hundreds of Caltowie, Yangya, and Bundaleer," by C. G. Stephens, M.Sc., R. I. Herriot, B.Ag.Sc., R. G. Downes, M.Agr.Sc., T. Langford-Smith, M.Sc., and A. M. Acock, B.A., D.Phil.

Bulletin No. .—" Studies of the Physiology and Toxicology of Blowflies. 10. A Histochemical Examination of the Distribution of Copper in *Lucilia cuprina.* 11. A Quantitative Investigation of the Copper Content of *Lucilia cuprina,*" by D. F. Waterhouse, M.Sc.

Bulletin No. .—" Post-Miocene Climatic and Geologic History and its Significance in Relation to the Genesis of the Major Soil Types of South Australia," by R. L. Crocker, M.Sc.

PLATE 1.

Manna-Formation in *Myoporum platycarpum*. (See page 159.)



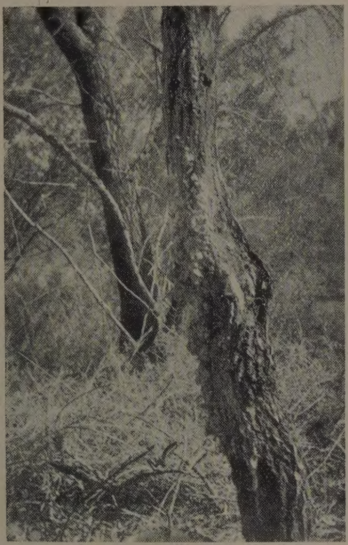


FIG. 1 (left).—A specimen of *M. platycarpum* showing manna extending over the entire length of the trunk.

FIG. 2 (right).—An enlarged view of the tree illustrated in Fig. 1 showing the dried exudate forming stalactites.

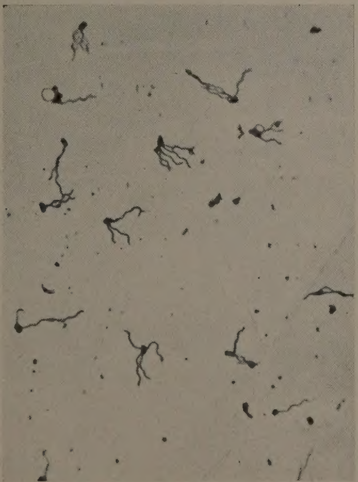


FIG. 3 (left).—A near view of another tree with collecting tins attached and showing the exudate forming a white frothing liquid.

FIG. 4 (right).—A photomicrograph of gram-negative bacteria showing peritrichous flagella. X750.

PLATE 2.

Manna-Formation in *Myoporum platycarpum*. (See page 159.)

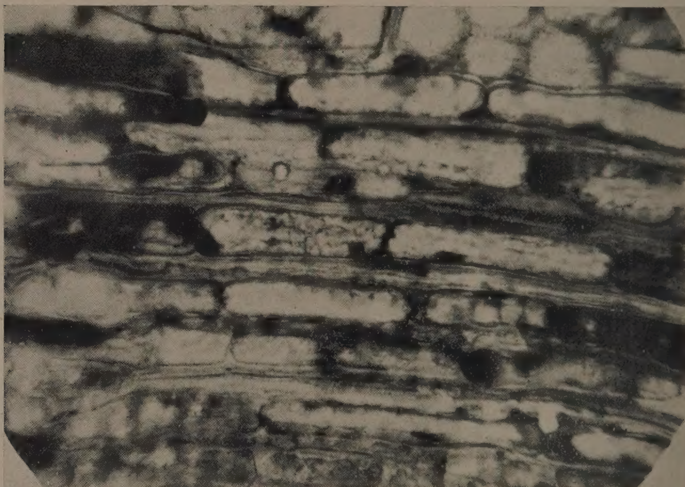


Fig. 1.—R.L.S. of the phloem of an exuding branch of *M. platycarpum* showing parenchymatous cells containing gum and tannin. X500.

Fig. 2.—R.L.S. of the phloem of a normal branch of *M. platycarpum* showing sieve-tubes with lateral plates. X750.

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